THE TWENTY-NINTH

ANNUAL REPORT

OF THE

MARYLAND AGRICULTURAL EXPERIMENT STATION.

COLLEGE PARK,

PRINCE GEORGE COUNTY, MARYLAND

1915–1916

PUBLISHED BY THE STATION

The Maryland Agricultural Experiment Station.

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The Station is located on the B. & O. R. R. and City and Suburban Electric Car Line, eight miles north of Washington, D. C.
Bell Telephone—Berwyn Exchange.

Visitors will be welcomed at all times, and will be given every opportunity to inspect the work of the Station in all its departments.

The Bulletins and Reports of the Station will be mailed regularly, free of charge to all residents of the State who request it.

ADDRESS:

AGRICULTURAL EXPERIMENT STATION,

College Park, Md.

LETTER OF TRANSMITTAL.

To His Excellency, E. C. Harrington, Governor,

Annapolis, Maryland.

Sir:—In accordance with the provisions of the Act of Congress, approved March 2, 1887, "To Establish Agricultural Experiment Stations," etc., I have the honor to transmit the Twenty-ninth Annual Report of the Maryland Experiment Station for the fiscal year ending June 30, 1916.

Yours truly,

H. J. PATTERSON,

Director of the Experiment Station.

June, 1916.

Contents

THE MARYLAND AGRICULTURAL EXPERIMENT STATION

VOL. 29. 1915-1916.

TWENTY-NINTH ANNUAL REPORT OF THE MARYLAND AGRICULTURAL EXPERIMENT STATION.

For the Fiscal Year Ending June 30, 1916.

By H. J. PATTERSON, Director.

To the Board of Trustees.

Gentlemen:—I submit herewith a report upon the work and expenditures of the Experiment Station during the past year.

Publications.

The bulletins issued by the Station give in the main the history and progress of the investigations conducted. As soon as an investigation is completed or when it has progressed far enough to make it desirable to make a partial report the results are published. From the nature of such work it can readily be understood that the bulletins must be issued at irregular intervals and that the number will vary from year to year.

The bulletins are sent free to all farmers in this State who desire them and also sent to all newspapers in Maryland. Our mailing list includes most of the agricultural periodicals in the United States and the principal libraries of the world.

The following bulletins were issued during this fiscal year:

Date.	No.	Subject.	Author.
July....1915	28	Annual Report for 1914-15.	H. J. Patterson.
Sept....1915	191	The Relation of Catalase and Oxidases to Respiration in Plants.	C. O. Appleman.
Jan....1916	192	Internal Actions of Chemicals on Resistance of Tomatoes to Leaf Diseases.	J. B. S. Norton.
Feb....1916	193	Test of the Availability of Different Grades of Ground Limestone.	L. B. Broughton, R. C. Williams, G. S. Frazee.
Feb....1916	194	Sudan Grass.	Nicholas Schmitz.
March..1916	195	Onions.	Thos. H. White.
April...1916	196	Methods and Problems in Pear and Apple Breeding.	W. R. Ballard.

Investigations in Progress.

The investigations that have been receiving attention during the past year were outlined in detail in the last annual report. No new work could be undertaken and some of the work already started could not be pushed vigorously as the State appropriations were not available.

Plans for taking up the Soil Investigations under the provision of the State act, have been completed and active work will be started at once. Dr. A. G. McCall, of the Ohio State University, has been secured as leader in the Soil Investigations. He entered upon his duties June first.

Ridgely Farm.

It has not been possible to start much work at the Ridgely substation as no funds were available for the work. This condition will be much improved next year and plans have been matured and things put in shape so that by the summer of 1917 there will be a number of investigations under way at Ridgely.

Finances.

The resources of the Experiment Station have remained the same for a number of years. This condition together with the increase in the cost of labor and supplies has made it impossible to take up much new work or to meet many of the demands for help. The past Legislature increased the appropriation for investigational work. This will permit the inauguration of a number of important investigations during the coming year.

The work of the Station has been conducted within the appropriations and all bills have been paid promptly when due.

The following report of the Treasurer shows the details of the expenditures for the past fiscal year:

MARYLAND AGRICULTURAL EXPERIMENT STATION

in Account with

THE UNITED STATES APPROPRIATIONS.

	Hatch Fund.	Adams Fund.
Dr.		
To appropriations for fiscal year, 1915-16.	$15,000.00	$15,000.00
Cr.		
By Salaries	10,921.34	8,724.26
" Labor	3,069.80	808.62
" Publications	689.39	....
" Postage and Stationery	66.43	64.91
" Freight and Express	....	74.78
" Heat, Light, Water and Power	4.87	181.79
" Chemicals and Laboratory Supplies	....	1,033.58
" Seeds, Plants and Sundry Supplies	12.99	441.19
" Fertilizers	114.00	....
" Library	14.15	34.00
" Tools, Machinery and Applicances	....	178.03
" Furniture and Fixtures	40.00	543.62
" Scientific Apparatus and Specimens	14.03	1,692.25
" Traveling Expenses	....	77.11
" Building and Land	53.00	618.35
" Balance	....	527.51
	$15,000.00	$15,000.00

The above is a true copy.

WIRT HARRISON, *Assistant Treasurer.*

MARYLAND AGRICULTURAL EXPERIMENT STATION

in Account with

THE STATE APPROPRIATIONS.

Dr.

	General Funds.	Hort'l Fund.
To Balance on hand July 1st, 1915......	$206.96	....
Received from State, fiscal year 1915-16..	11,455.18	4,000.00
To Interest on Deposits and Refunds.....	....	7.43
	$11,662.14	$4,007.43

Cr.

By Overdraft, July 1st, 1915...........	....	$51.59
" Labor	$775.00	798.00
" Salaries	2,568.98	152.25
" Publication	801.54	336.30
" Postage and Stationery.............	91.49	38.26
" Freight and Express...............	61.06	109.40
" Heat, Light and Water..............	151.66	74.37
" Chemical and Laboratory Supplies...	1.20	....
" Seeds, Plants and Sundry Supplies..	1,044.98	468.96
" Fertilizers	398.95	60.00
" Feeding Stuffs.....................	839.59	....
" Library	108.63	4.61
" Tools, Implements and Machinery....	1,126.78	332.12
" Furniture and Fixtures.............	18.85	15.40
" Scientific Apparatus................	63.25	....
" Live Stock.........................	571.40	....
" Traveling Expenses.................	157.03	128.43
" Contingent Expenses................	2,156.38	136.11
" Building and Repairs...............	515.41	7.80
" Balance	209.96	1,293.83
	$11,662.14	$4,007.43

The above is a true copy.

WIRT HARRISON, *Assistant Treasurer.*

MARYLAND AGRICULTURAL EXPERIMENT STATION

in Account with

FARM SALES.

Dr.

To Balance July 1st, 1915	$338.88
" Receipts from Sale of Farm Products and for Labor of Men and Teams	$8,515.85
" Overdraft Due June 30th, 1916	226.98
	$9,081.71

Cr.

By Salaries	$1,115.00
" Labor	7,016.07
" Publications	....
" Postage and Stationery	52.48
" Freight and Express	304.30
" Heat, Light and Water	67.49
" Seeds, Plants and Sundry Supplies	56.43
" Feeding Stuffs	....
" Live Stock	237.00
" Traveling Expenses	170.47
" Contingent Expenses	....
" Building and Repairs	28.87
" Furniture and Fixtures	8.40
" Tools, Implements and Machinery	25.20
	$9,081.71

The above is a true copy.

WIRT HARRISON, *Assistant Treasurer.*

MARYLAND AGRICULTURAL EXPERIMENT STATION

in Account with

THE RIDGELY FARM ACCOUNT.

Dr.

To Balance July, 1915	$399.43
Received from State Appropriation, 1915-1916	875.00
Received from Sale of Produce	712.31
	$1,986.74

Cr.

By Salaries	$250.00
" Labor	689.54
" Postage and Stationery	27.33
" Freight and Express	21.11
" Heat and Light	1.31
" Chemical Supplies	2.57
" Sundry Supplies	189.50
" Fertilizers	243.31
" Feed	30.47
" Tools, Implements and Machinery	165.63
" Furniture and Fixtures	9.15
" Building and Repairs	66.14
" Insurance	95.54
" Balance	195.14
	$1,986.74

The above is a true copy.

WIRT HARRISON, *Assistant Treasurer.*

THE MARYLAND STATE BOARD OF AGRICULTURE

in Account with

THE BIOLOGICAL LABORATORY FUND.

Dr.

To Balance on Hand July 1st, 1914	$1,143.53
Received from Sale of Serum, Hogs, Meat, etc	8,924.96
	$10,068.49

Cr.

By Salaries	$2,038.00
" Labor	701.00
" Laboratory Supplies	9.05
" Feed	708.85
" Live Stock	4,167.50
" Tools and Implements	13.50
" Scientific Apparatus	224.57
" Heat and Light	25.47
" Library	....
" Postage and Stationery	25.56
" Contingent Expenses	27.38
" Sundry Supplies	295.08
" Building and Repairs	69.22
" Freight and Express	6.28
" Furniture and Fixtures	2.20
" Balance	1,754.83
	$10,068.49

The above is a true copy.

WIRT HARRISON, *Assistant Treasurer.*

THE STATE BOARD OF AGRICULTURE

in Account with

THE STATE SEED INSPECTION FUND.

Dr.

Received from State Appropriation, 1915-1916	$4,500.00

Cr.

By Overdraft	$1,188.18
" Salaries	1,908.00
" Labor	421.27
" Tools and Implements	.64
" Scientific Apparatus	4.95
" Heat and Light	10.80
" Postage and Stationery	39.10
" Contingent Expenses	5.00
" Sundry Supplies	54.12
" Building and Repairs	3.00
" Furniture and Fixtures	85.25
" Traveling Expenses	259.58
" Balance	520.11
	$4,500.00

The above is a true copy.

WIRT HARRISON, *Assistant Treasurer.*

THE MARYLAND AGRICULTURAL EXPERIMENT STATION

BULLETIN No, 191. SEPTEMBER, 1915.

RELATION OF CATALASE AND OXIDASES TO RESPIRATION IN PLANTS.

By Charles O. Appleman.

In carrying out their manifold activities of life, plants do work which is none the less real because it is slow. One of the verities of physics requires the expenditure of energy for the performance of work of any kind. Therefore, energy must be made available in plant tissues. Respiration is a process which furnishes energy and as such is one of the most important processes in plant metabolism. It unlocks in the tissues where it is needed, energy of the sun which is stored up in complex organic compounds by photosynthesis.

Respiration may be considered as an oxidation process in the sense that the final products are the same as ordinary combustion in air; namely, carbon dioxide, water and energy. It is, however, a much more complex process and is capable of bringing about at low temperatures, the oxidation of organic substances as sugar, which, in the laboratory, is accomplished only by employing very high temperatures and powerful reagents. The living cells produce a chemical mechanism which is responsible for the activation of oxygen in this physiological oxidation. The character of this mechanism has long held the interest of physiologists and in spite of the enormous amount of work done toward the solution of the problem, the literature on the subject is still largely hypothetical.

The work of Kostytchew[11] has furnished the final proof that respiration in higher plants occurs in two fairly distinct stages; a primary, anaerobic stage, and a secondary stage which results in the oxidation of the products of the first stage of the process. Recent investigations by Palladin and others all seem to point to the conclusion that the entire process of respiration is due to the summation of enzyme activities. This is especially confirmed by the fact that plants killed without destruction of the enzymes, continue to give off CO_2 and absorb oxygen. Although Kostytchew[10] has shown that

anaerobic respiration is not always identical with alcoholic fermentation, yet the latter process undoubtedly plays the most important part in the anaerobic respiration of most plants. Since zymase is an established enzyme of alcoholic fermentation it may be classed as a respiratory enzyme. The role of other enzymes in anaerobic respiration is not so well established and still less is definitely known regarding the enzymes concerned in the secondary or aerobic process of respiration.

The guaiacum reaction seems to have been the starting point for our first knowledge of oxygen activators and carriers in plants. Planche[16], as early as 1809, observed that guaiacum is rapidly blued by the fresh root of horse radish. The real impetus for a better understanding of the guaiacum reaction and oxygen activation was furnished by Schoenbein[18] through his discovery of ozone in 1840 and his later papers on bluing of guaiacum by substances in the fresh tissues of plants. This remarkable observer explained the oxidizing action of these substances on the supposition that they ozonize the air and then combine with the ozone thus produced to form active ozonides. These are unstable substances, capable of giving up their oxygen to other substances much less readily oxidizable. Although Schoenbein's theory of oxygen activation has been greatly modified in the light of later knowledge, he must nevertheless be given the credit for discovering the properties of oxygen activators in plants which later placed them in the category of enzymes.

The term oxidizing ferment was first introduced in 1877 by Traube in his later writings on fermentations. According to him, the oxidizing ferments are those which combine loosely with free oxygen, forming unstable compounds which give up their oxygen to other less readily oxidizable substances. Bertrand[6] was led to believe that the oxidizing ferments are more or less specific in their action, so he proposed the term "oxidases" as a group name for these ferments. Besides these substances in certain extracts and tissues which have the power of rendering active the oxygen of the air, others had been known for a long time which render active the oxygen of hydrogen peroxid. In 1898, Linossier[13] introduced the name "peroxidases" for these latter substances. Bach and Chodat[7] found that peroxidases can activate not only hydrogen peroxid, but also organic peroxides. This fact, in connection with other important observations led them to conclude that the oxidases are not single enzymes, but mixtures of peroxidases and peroxide-forming substances. To these latter substances they gave the name "oxygenase."

Oppenheimer[15] has classed the oxidation enzymes in the following groups: 1. alcoholases, 2. aldehydases, 3. purinoxidases, 4. phenolases, 5. tyrosinases, 6. peroxidases. These group names are taken from the classes of substances now generally recognized as acted upon by oxidation enzymes. Oppenheimer realizes the provisional char-

acter of this classification and states further that "the oxidation ferments represent the darkest Africa in the ferment world."

The phenolases accelerate only the oxidation of aromatic substances and are thus the oxidizing enzymes that are usually measured by the oxidase reagents in common use at the present time. The oxidases referred to in this paper include only the phenolases of Oppenheimer's classification.

Practically all attempts to explain the mechanism of respiration have assigned these long established oxidative forces a role in cell oxidations, although this relation has never been experimentally proven. The chief difficulty lies in the fact that the demonstrable oxidases are capable of accelerating the oxidation only of aromatic compounds which are either entirely foreign to plant tissue or present only in insignificant amounts. In other words, they have no direct action on the ordinary substances consumed in respiration, for example, sugar. When it was recognized that respiration occurs in two distinct stages the oxidases were relieved of the responsibility of direct oxidation of complex substances; since on this basis they would be concerned only in the oxidation of the decomposition products of the anaerobic stage. But these products are aliphatic substances, incapable of being directly oxidized *in vitro* by the oxidases, therefore, the situation remains nearly as perplexing as ever.

Palladin[17] and his co-workers have elaborated a very ingenious hypothesis to explain the mechanism of respiration. In its present form, it comes the nearest of anything yet offered to overcome the chief difficulties encountered in ascribing to the oxidases a function in respiration. The essential features of Palladin's hypothesis may be briefly summarized as follows: The first product of sugar fermentation is some aldehyde. This can be partially converted into acid by the Cannizzaro reaction or totally into acid by the Schardinger mechanism. By means of carboxylase, carbon dioxide is split off from the carboxyl in the acids formed. Thus the total carbon dioxide expired during respiration is anaerobic in origin. The Schardinger mechanism requires the presence of an acceptor for the hydrogen formed by the water decomposition. According to Palladin, the respiratory pigments perform this function and are thereby reduced to chromogens. At this point the oxidases enter the field of action and oxidize the chromogens back to pigments by the removal of the hydrogen and the formation of water. All of the oxygen consumed during respiration is used for the oxidation of the hydrogen in the pigment acceptors. The water arising during respiration is entirely aerobic in origin. Since the chromogens are aromatic substances they fall into the same general class of substances acted upon by the demonstrable oxidases.

Palladin's explanation seems very simple, but it must be remembered that it is still in the hypothetical stage. It has been, however, a working basis for much valuable work on respiration.

It has been known for a long time that plant and animal tissues have the power to decompose hydrogen peroxid with the evolution of molecular oxygen. Schoenbein[19] seems to have been the author of the conception that the power to decompose hydrogen peroxid is a general property of all soluble ferments. This idea prevailed until Loew[12] found that it was entirely erroneous. He proved that the decomposition of hydrogen peroxid by plant and animal tissues is due to a special enzyme, to which he gave the name "catalase." All later investigations tend to verify the specific nature of catalase, but some seriously question its place in the category of enzymes.

When one considers the abundance and wide distribution of catalase in plant and animal tissues, it is natural to suppose that it plays some important role in metabolism. But so far its function has not been definitely established. Much theory based upon rather scanty experimental data has attempted to directly or indirectly connect catalase activity with the oxidative forces of the cell. The work of Lesser[14] seems to furnish the most conclusive evidence in this direction. He made a large number of catalase determinations in different small animals and in different organs and tissues of the same animal and concluded that catalase is connected with physiological oxidations. Although a strict interpretation of his results does not show a casual relation between catalase and cell oxidation, it does show a remarkable correlation. Zieger[21] also made a study of the catalase content of nearly all groups of animals except the protozoa. He did not succeed in establishing a relation between respiration and catalase content, but he did show that there is some relation between catalase content and metabolism. He brought out this fact by the study of the catalase content in organs which are very active chemically, as the liver and kidney. The evidence from the plant side, for such a relation, is indirect and inconclusive. This can be partly explained by the destructive action on catalase of the acid in the plant extract, rendering it difficult to make accurate quantitative measurements.

Passing over the many speculations regarding the protective action of catalase as well as its role in reductions and in alcoholic fermentation, brief mention will be made of a conception advanced by Woker[20] and more recently elaborated by Begemann.[8] They think that catalase and peroxidase actions are only different manifestations of oxygenase whose action may be explained in the following manner: The living cell contains a simply constituted aldehyde and also a peroxid. These two react forming a secondary peroxid, which may give off active oxygen and is thus an oxidizing agent. It may oxidize substances like pyrogallol. If the secondary peroxid unites with hydrogen peroxid, the new compound may be capable of reacting with other chromogens. If an excess of hydrogen peroxid is present molecular oxygen is liberated, thus showing the catalase action. The aldehyde itself may react with easily reducible substances thus act-

ing as a reductase. Begemann's theorizing may be logical enough, but one is inclined to question some of his experimental data, especially those relating to catalase as the measurements were made in plant juices with no precautions to neutralize the acids.

Bach[9] has made some recent experiments which seem to disprove the aldehyde nature of peroxidase, catalase and phenolase. He claims that each of these enzymes is an individual whose reactions cannot be regarded as different manifestations of an aldehyde as claimed by Woker.

It is evident from the foregoing brief review of the literature that the role of both the oxidases and catalase in respiration is almost entirely hypothetical. Respiration in potato tubers is subject to quite wide variation under natural conditions and can be greatly influenced by certain artificial treatments. Since these tubers also contain very active oxidases as well as catalase, they were chosen as favorable material to make an experimental study of the relation of catalase and oxidase activity to respiration.

Methods.

Respiration.—The rate of respiration was determined by the amount of CO_2 expired from the tubers. No attempt was made to control the temperature, but all measurements that are compared were made at the same time and under identical conditions. About a kilo of tubers were allowed to respire twenty-four hours for each determination.

Oxidase.—A manometric method was used for the oxidase determinations; the oxygen absorbed during the reaction being measured by the change of pressure within Bunzel's[3] simplified apparatus. Both pyrocatechin and hydrochinon were first employed as the oxidizable substance, but it was soon found that they showed the same general relations in respect to oxidase activity under different conditions. Since the reaction with hydrochinon was very slow as compared with that of pyrocatechin, its use was soon abandoned in favor of pyrocatechin as the sole reagent. From Bunzel's[4] work on the "Oxidases in Healthy and in Curly-Dwarf Potatoes" in which he used 18-ring compounds, it may be concluded that the use of one favorable compound of this nature would give just as valuable comparative results as use of a large number. He found a wide variation in the amount of oxygen absorbed by the different compounds, but aside from one or two exceptions, they all showed the same general relation of oxidase activity in the different juices examined. In another paper, Bunzel[5] states: "No matter what the derivation of the plant juice is, the relative oxidizability of the various compounds is approximately the same."

Bunzel's apparatus, of the size now on the market, required very small amounts of juice for a determination of the oxidase in the

tubers of the principal variety employed in this work. In order to avoid errors in the measurement of extremely small quantities of juice, resort was made to the following dilution method: 2 c. c. of juice were measured into 10 c. c. of distilled water and after thorough mixing, without violent shaking, 2 c. c. of the dilution were placed in the long arm and 5 milligrams of oxidizable substance in the short arm of the apparatus. The determinations were made in a constant temperature box of 33°C. During the reaction the apparatus was shaken constantly at the rate of 180 complete excursions per minute. After repeated trials with the diluted juice, it was found that the rate of shaking within wide limits had no effect on the total amount of oxygen absorbed; but the velocity of the reaction seemed to be greatest at about the amount of shaking decided upon for the standard in this work. The shaking was accomplished by means of a home-made apparatus which did the work so satisfactorily and cost so little that it was thought worth while to print a photograph of the apparatus. It may serve as a suggestion to others who wish to devise an inexpensive shaker to be used in connection with Bunzel's oxidase apparatus. The material, consisting of cypress lumber, paint, shellac and hardware, cost about one dollar. The work was done in the laboratory work shop.

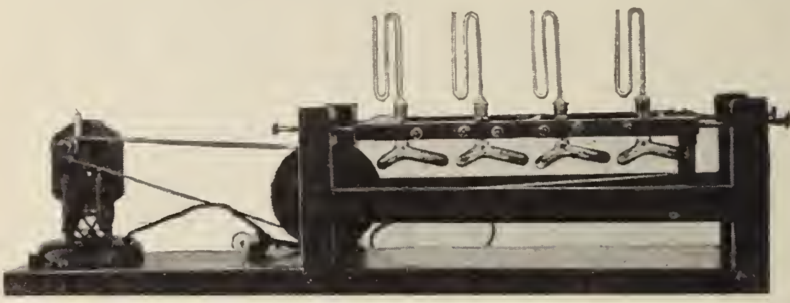

Fig. 1. Shaking Machine.

NOTE.—The motor was placed on the outside of the thermostat. This is necessary as the heat of the motor disturbs the temperature control. Belt connection with the apparatus was made through two small holes in the wall of the thermostat.

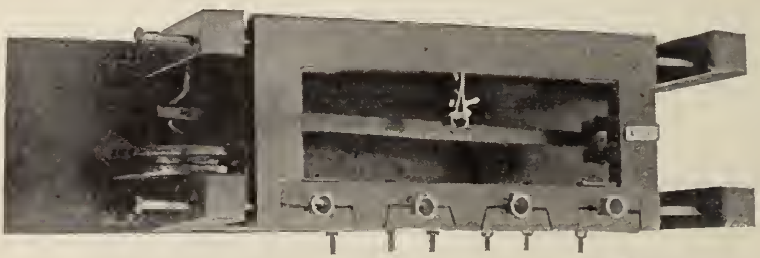

Fig. 2. Shaking Machine; looking down on top of apparatus.

The manometer readings recorded in this paper are those made at the end of one hour, unless otherwise noted, and represent the oxidase activity in .33 c. c. of undiluted juice. Although in the case of pyrocatechin a very slow oxidation continued for several hours, it came to a comparatively definite end point after an hour.

Catalase.—The potato juice for the catalase determinations was prepared by grating the tubers with calcium carbonate in the manner described by the writer in a previous paper.[1] The calcium carbonate neutralizes the free acids which very rapidly destroy the catalase in the juice. The catalase measurements were made in the same kind of apparatus used for the oxidase measurements, except that the apparatus was graduated to read positive pressures. The juice for a catalase determination was diluted in the following manner: 2 c. c. of juice were added to 25 c. c. of distilled water. The juice was thoroughly mixed with the water by rotating the flask 25 times. One c. c. of the mixture was carefully measured into the long arm of the apparatus and 1 c. c. of Oakland dioxogen (hydrogen peroxid) in the short arm. The determinations were made in the same constant temperature box and shaken with the same shaker described under oxidase. The manometer reading at the end of five minutes constant shaking was considered the measure of catalase activity in .074 c. c. of juice. All the catalase results in the experimental part represent the activity in this amount of juice, except when otherwise noted.

The oxidase and catalase measurements were all made in duplicate and those whose results were not in close agreement were discarded.

It was very desirable to use the same lot of juice for both catalase and oxidase measurements, but before this was possible it was necessary to determine what effect the $CaCO_3$ would have upon the oxidase activity. To this end, tubers were cut in half longitudinally so that each piece contained exactly one-half of the seed and stem ends. One piece was grated without $CaCO_3$ and the other by dipping into $CaCO_3$ in the usual way for catalase determinations. Oxidase measurements were then made in the juice thus prepared. The tubers were all of the same variety, but not with the same previous history, especially as regards cultural and storage conditions; this accounts for the greater oxidase variation than is usually due to individual variations in the same lot.

TABLE 1.

Effect of $CaCO_3$ on the oxidase activity in the juice from potato tubers.

Tuber.	Manometer readings expressed in centimeters of mercury.	
	The half grated with $CaCO_3$	The half grated without $CaCo_3$
1	–2.25	–2.45
2	–1.80	–1.80
3	–2.45	–2.15
4	–2.00	–2.05
5	–2.00	–2.20
6	–2.20	–2.10
7	–1.75	–1.70
Average.	–2.06	–2.06

After seven determinations it became quite evident that the $CaCO_3$ exercises no appreciable effect upon the oxidase activity in potato juice, according to the method here employed for its measurement. Therefore, the oxidase measurements recorded in this paper were made with samples of the lot of juice used for the catalase determinations, unless otherwise noted.

The above conclusions regarding the effect on oxidase activity of $CaCO_3$ in the juice apply only with pyrocatechin. The effect may be otherwise with other chromogens. In fact, the presence of $CaCO_3$ in the juice seems to depress the oxidation of aloin, while the peroxidase activity is actually stimulated both in the case of aloin and guaiaconic acid.

Experimental Results.

Respiration of potato tubers may be greatly accelerated by various artificial treatments. The exact nature of their action is unknown. They may cause a greater production of oxidizable substances or they may act upon the respiratory enzymes. It is also conceivable that the action may be entirely of secondary nature. The following experiments show the degree of respiratory acceleration and the effect on oxidase and catalase activity produced by selected treatments.

Ethyl Bromide.—In a previous paper the writer[2] has shown that short exposures to ethyl bromide gas will about double the respiration in old McCormick potatoes. This treatment was repeated and catalase and oxidase determinations made on the same tubers used for respiration. Duplicate determinations on untreated tubers were made at the same time and under the same conditions. The results show that

the treatment has no effect whatever on the oxidases. The catalase activity on the other hand is greatly increased in the treated tubers.

TABLE 2.

Respiration of McCormick potatoes after an exposure of the tubers to ethyl bromide gas for thirty minutes.

Date of Measurement.	Time elapsed after treatment with Ethyl Bromide gas.	Milligrams of CO_2 per kilo per hour.		Ratio.
		Untreated.	Ethyl Bromide gas—30 min.	
February 12..	1 hour.	19.17	37.94	1 : 1.98
February 24..	12 days.	16.60	18.54	1 : 1.27

TABLE 3.

Oxidase activity in juice from McCormick potatoes after an exposure of the tubers to ethyl bromide gas for thirty minutes.

Experiment.	Time elapsed after treatment with Ethyl Bromide gas.	Quantity of juice used.	Manometer readings expressed in centimeters of mercury.	
			Untreated.	Ethyl Bromide gas—30 min.
	Hours.	c. c.		
1	1	1	–4.4	–4.5
2	1	1	–4.5	–4.5
3	2	.5	–3.0	–3.2
4	24	.5	–3.2	–3.4
5	24	.2	–1.0	–1.0
6	48	.33	–2.5	–2.5
	Average............		–3.1	–3.18

TABLE 4.

Catalase activity in juice from McCormick potatoes after an exposure of the tubers to ethyl bromide gas.

Experiment.	Time elapsed after treatment with Ethyl Bromide gas.	Manometer readings expressed in centimeters of mercury.	
		Untreated.	Ethyl Bromide gas—30 min.
	Hours.		
1	20	+2.6	+3.5
2	21	+2.2	+3.6
3	40	+2.0	+3.5
4	40	+2.4	+3.5
Average............		+2.3	+3.53

Cold Storage.—If tubers are stored for a few weeks at low temperatures and then brought to room temperature, they respire much more rapidly than tubers of the same lot which were not subjected to the cold storage. The effect on the catalase and oxidase is almost identical with that under the ethyl bromide treatment, if the cold storage temperature does not fall below 3°C. In a previous work the writer found that at temperatures around 0°C. or below, the catalase activity is actually less than in normally stored tubers. This was accounted for in the destruction of the catalase by free acids. The presence of free acids is demonstrated by the acid exudate from tubers stored at this very low temperature. The accumulated sugar in the cold storage tubers may bear a causal relation to the increased respiration since the rate of respiration falls to normal with the disappearance of the sugar.

TABLE 5.

Effect of cold storage on respiration of McCormick potatoes.

Date of Measurement.	Milligrams of CO_2 per kilo per hour.		Ratio.
	Tubers stored at room temperature	Tubers stored at 3°C. for 20 days.	
February 18	12.50	35.15	1 : 2.81

TABLE 6.

Catalase and oxidase activity in the juice from McCormick tubers after a period of cold storage.

Experiment.	Manometer readings expressed in centimeters of mercury, using .1 cc. of juice for catalase and .5 cc. for oxidase.			
	Tubers stored at room temperature.		Tubers stored at 3° C. for 20 days.	
	Catalase.	Oxidase.	Catalase.	Oxidase.
1	+2.4	–3.0	+4.2	–2.9
2	+3.5	–2.9	+4.5	–2.7
3	+3.6	–2.9	+4.2	–2.3
4	+2.4	......	+4.4	......
Average.	+2.97	–2.93	+4.32	–2.63

Effect of Greening.—Greening of potato tubers in light is a very familiar phenomenon. One of the physiological changes concomitant with the greening is a rise in respiration. This offered a good opportunity to make a quantitative study of catalase and oxidase in relation to a change in respiration naturally induced. In connection with other work, the writer found in different stages of greening, a much greater rise in respiration than in the experiments here recorded. Even with the degree of acceleration shown in Table 7, there is an increase in catalase in the green tubers. But again the oxidase activity is not increased with a rise in respiration; in fact, it is a little less in the green tubers than in the ungreened ones.

TABLE 7.

Effect of greening on respiration, catalase and oxidase.

Experiment	Milligrams of CO_2 per kilo per hour		Manometer readings expressed in centimeters of mercury			
			Catalase		Oxidase	
	Normal	Green	Normal	Green	Normal	Green
1	17.14	19.50	+2.5	+2 8	--2.35	--2.1
2	14.32	16.24	+2.1	+2.5	--2.2	--2.1

Effect of Sprouting.—Whole tubers of many varieties produce sprouts only from the buds on the seed end. Other varieties tend more to uniform sprouting from all the eyes of the tuber. But even in the latter varieties, many individual tubers may be found which bear sprouts only on the seed end.

Tubers bearing sprouts only on the seed ends were cut in half and respiration measured separately in the seed and stem halves. It was found that respiration is always much higher in the seed halves when the sprouts are left on. This difference seems to be greater during incipient sprouting than after the sprouts have attained considerable size. How much of the increased respiration in the seed ends bearing the sprouts is due to the respiration of the sprouts themselves is difficult to determine. It is probable that the growing sprouts induce a higher respiration in the tissue of the tuber adjacent to the sprouts, especially in the case of very small sprouts. If the sprouts are removed just prior to the measurement of respiration the results are quite different and depend upon the variety in question. In all cases the difference in respiration between the seed and stem ends is suddenly reduced. In McCormick tubers it always remains a little higher in the seed halves.

The behavior of the catalase activity in the two ends of the McCormick tuber is practically identical with that of respiration. No difference in the oxidase activity of the two ends could be detected by the Bunzel method, using either pyrocatechin or pyrogallol as the oxidizable substance.

The results of a large number of colorimetric determinations, using aloin as the oxidizable substance, show that this method does not agree with the Bunzel method in indicating the relative oxidase activity in the two ends of McCormick tubers. The colorimetric method consistently showed a greater oxidase activity in the stem half of the tuber, although this half always exhibited a lower rate of respiration. Therefore, notwithstanding the disagreement between the two methods, neither disclosed any relation between oxidase activity and the intensity of respiration.

Unpublished results on respiration of other varieties of potatoes show the danger of drawing general conclusions from a single variety. In one case at least the relative intensity of respiration of the two ends of the tuber with sprouts removed was just the reverse of that found in McCormick tubers. Up to the present time catalase and oxidase measurements have not been made in the tubers of this variety. However, when the same variety is used for both the respiration and enzymes measurements the results from a single variety permit one to draw conclusions respecting the thesis of this paper.

TABLE 8.

Comparison of respiration in seed and stem ends; McCormick tubers, sprouting only from seed ends.

Sprouts	CO_2 per kilo per hour, expressed in ratio of seed and stem ends.	
	Seed ends.	Stem ends.
not started	100	93.5
not started	100	93.2
on during measurement	100	58.2
removed prior to measurement	100	80.2
removed prior to measurement	100	89.3

TABLE 9.

Catalase and oxidase activity in seed and stem ends; McCormick tubers sprouting only from seed ends.

Date of measurement.	Average length of sprouts.	Manometer readings expressed in centimeters of mercury.			
		Seed end.		Stem end.	
		Catalase.	Oxidase.	Catalase.	Oxidase.
March 20	0	+2.4	−1.7	+2.1	−1.9
March 22	0	+3.1	−2.1	+2.7	−2.2
March 25	8 mm	+4.0	−2.2	+3.1	−2.2
April 6	12 mm	+3.6	−2.25	+3.0	−2.1
Average		+3.36	−2.06	+2.72	−2.12

Comparison of Different Varieties.—Tubers from different varieties, but under identical storage and sprouting conditions, were found to possess different rates of respiration. This fact being established, experiments were next planned to determine if there is a corresponding difference in either the catalase or oxidase activity in the varieties showing a difference in rate of respiration. A varietal influence on both catalase and oxidase was soon discovered, although it is much greater in some cases than in others. The most striking difference was noted in the case of McCormick and Carmin No. 1. These

are both late varieties, but the McCormick tubers were grown in Maryland, while the Carmin No. 1 tubers were grown in New York. Both varieties were under identical storage conditions for nearly two months prior to the date of experiment and both bore sprouts of practically the same vigor as determined by length and total weight. The sprouts were removed just before the measurement of the rate of respiration. The Carmin No. 1 tubers respired more rapidly than the McCormick tubers. The catalase activity in the two varieties was strikingly correlated with respiration. On the other hand, the oxidase activity was four times greater in the McCormick tubers. Tables 10 and 11 show typical experiments with these two varieties. In this study of varietal influence no account was taken of cultural conditions; therefore, it is possible that these conditions may have had some influence on the results. Even though this were true, it would not alter the value of the results in showing the relation of catalase and oxidase activity to respiration.

TABLE 10.

Respiration of tubers from two different varieties. All conditions of experiment identical in both cases.

Date of Measurement.	Milligrams of CO_2 per kilo per hour.	
	McCormick	Carmin No. 1
April 21	12.83	17.36

TABLE 11.

Catalase and oxidase activity in juice from tubers of two different varieties.

Date of measurement.	Manometer readings expressed in centimeters of mercury.			
	Catalase.		Oxidase.	
	McCormick.	Carmin No. 1.	McCormick.	Carmin No. 1.
April 14.....	+2.3	+3.3	–2.2	–.60
April 23.....	+2.85	+3.15	–2.6	–.64

Summary and Conclusions.

The introduction contains a brief discussion of the function of respiration in plants and the chemical mechanism which is responsible for this physiological oxidation. This is followed by an historical resumé of oxygen activators and carriers in plants and the origin of the various names applied to them. Certain important hypotheses are then summarized, which attempt to assign these oxidative forces in the cell a role in respiration.

The important literature on catalase is briefly reviewed, especially that concerned with its function in respiration.

The task in the experimental part was a study of the relation of catalase and oxidase activity in potato juice and the intensity of respiration in the tubers under different conditions. Potato tubers are especially favorable material for a study of this kind, since respiration in the tubers is not only greatly accelerated by various artificial treatments, but is subject to great fluctuations under natural conditions, for example, after storage at low temperatures, greening and sprouting. The rate of respiration also varies in different parts of the same tuber and tubers of different varieties. The modification of the intensity of respiration in the tubers under such conditions was determined and at the same time measurements were made of both the oxidase and catalase activity in the juice. The data seem to justify the following conclusions:

1. *The oxidase content in potato juice gives no indication of the intensity of respiration in the tubers. In other words, there is no correlation between oxidase activity and the rate of respiration in these organs.* The author does not disclaim any role of the demonstrable oxidases in respiration, but they certainly are not the controlling factor in regulating the rate of respiration in potato tubers. The limiting factor must lie elsewhere. Among the possibilities may be mentioned the following: oxygen supply to the respiring tissue, availability of oxidizable material, other enzymes, especially those concerned with the anaerobic process of respiration, respiratory chromogens, etc.

2. *Catalase activity in the potato juice shows a very striking correlation with respiratory activity in the tubers.*

Literature Cited.

1. Appleman, Charles O., Some Observations on Catalase. Bot. Gaz., 50: 182-192. 1910.
2. Appleman, Charles O., Study of Rest Period in Potato Tubers. Maryland Agr. Expt. Sta. Bull. 183: p. 222. 1914.
3. Bunzell, H. H., A Simplified and Inexpensive Oxidase Apparatus. Jour. Biol. Chem. 17: 409-411. 1914.
4. Bunzel, H. H., Oxidases in Healthy and in Curly-Dwarf Potatoes. Jour. Agr. Research, 2: 373-403. 1914.
5. Bunzel, H. H., Biological Oxidizability and Chemical Constitution. Jour. Biol. Chem. 17: 36. 1914.
6. Bertrand, Sur les rapports qui existent entre la constitution chemique des composes organiques et leur oxydabilite sous l'influence de la laccase. Bull. Soc. Chim. par. 15: 793. 1896.
7. Bach and Chodat, Untersuchungen uber die Rolle der peroxyde in der Chemie der lebenden Zelle; II, Ueber Peroxydbildung in der lebenden Zelle. Ber. d. deut chem. Gesell. 36: 600-605. 1903.
8. Begemann, Otto H. K., Plant Oxidation Enzymes. Arch. Ges. Physiol. 161: 45-232. 1915.
9. Bach, A., Individuality of Oxidizing and Reducing Enzymes. Arc. Sci. Phys. Nat. 37: 59-71. 1915.
10. Kostytschew, S., Über das Wesen der anaeroben Atmung verschiedener Samen Pflanzen. Ber. Deut. Bot. Gesell. 38: 125. 1913.
11. Kostytschew, S., Über den Einflus vergorener Zucherlosungen auf die Atmung der Weisenkein. Biochem. Zeitschr. 23: 137; 27: 326.
12. Loew, O., Catalase, a New Enzyme of General Occurrence. U. S. Dept. Agr., Rep. 68, p. 47. 1901.
13. Linossier, Contribution a l'etude des ferments oxydants. Compt. Rend. Soc. Biol. 50: 373-375. 1898.
14. Lesser, Ernst F., Zur Kenntnis der Katalase. Zeitschr. f. Biol. 49: 575. 1907
15. Oppenheimer, C., Die Fermente. Band 11, p. 754. 1913.
16. Planche, Note zur la sophistication de la résine de jalap et sur les moyens de la reconnaître. Bull de Pharm. 2: 578-580. 1810.
17. Palladin, 2, Ueber die Bedeutung des Wassers bei den Prozessen der alkolischen Garung und der Atmung der Pflanzen. Biochem. Zeitschr. 60: 171-201. 1914.
18. Schoenbein, Beobachtung ueber den bei der Elektrolyzation des Wassers und dem Ausstromen der gewöhnlichen Elektricität aus Spitzen sich entwickelnden Geruch. Poggendorf's Annalen. 50: 616-635. 1840.
19. Schoenbein, Ueber die katalytische Wirksamkeit organischer Materien und deren Verbreitung in der Pflanzen-und Tierwelt. Jour. f. prakt. Chem. 98: 323-344. 1863.
20. Woker, G., Zur Theorie der Oxydationfermente. Zschr. allg. Physiol. 16: 341-351. 1914.
21. Zieger, Rudolf, Catalases of the Lower Animals. Biochem. Zeitschr. 69: 39-110. 1915.

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INTERNAL ACTION OF CHEMICALS ON RESISTANCE OF TOMATOES TO LEAF DISEASES.

J. B. S. Norton.

The internal application of remedies for plant disease would naturally be thought of by many on account of such treatment for animals. Many attempts to treat plants in this way have been made since long ago, usually without regard to the totally different structure and mode of life of plants and animals. The inevitable failure of such crude methods as were used and the corresponding success with external treatment have brought about the development of plant protection and medication almost entirely along the latter line. The attention of both practical men and investigators in plant disease treatment has been given in recent years mostly to perfecting the spraying operations and developing other methods of external treatment.

Some serious study has, however, been given to working out an "inner therapy" for plants.

Soil Applications.

The effect on plant disease of various soils and fertilizers in the soil has been considered by many since Liebig, who thought the potato blight due to lack of potash and phosphorus.[1] Laurent[2] and Lepoutre[3] have investigated the rotting of potatoes by bacteria, ordinarily not parasitic, whose attack was favored or hindered by different fertilizers. Laurent has also studied the relation of clover dodder to fertilizers.[4]

1 See Sorauer. Pflanzenkrankheiten. 3rd edition. 2:143. 1908. See Rostrup. Tidsskr. for Landoekonomie. 1890, for effect of fertilizers on attack of clover by dodder.
2 Ann. de l' Inst. Pasteur, vol. 13, 1899.
3 l. c. 14: 304. 1902.
4 Zeitschr. f. Pflanzenkr. 12:343.

Pichi[1] found benefit against grape mildew from applying copper sulfate in the soil about the attacked vines.

Marchal[2] was able to produce in lettuce plants a distinct resistance against mildew (*Bremia lactucae Regel*) by copper sulfate 3 to 4 parts per 10,000 of the nutrient solution in which the plants were grown. Five to seven parts per 10,000 was found to be injurious to the lettuce; while concentrations below 3 per 10,000 were without effect. Iron sulfate had no immunizing effect. Manganese sulfate and potash salts were also without certain result. Nitrates and phosphates favored infection.

Laurent[3] obtained negative results in trying to immunize potatoes by treatment with copper sulfate.

Direct Injection Methods.

The method of direct injection has been revived in recent years and a number of attempts made to adapt it to the requirements of plant anatomy and physiology. Mokrschetzki and Chewyreuv in Russia,[4] and Bolley in America,[5] have made use of both nutrients and poisons to control disease by injection into trees. From 1908 to 1912, the writer carried on a series of investigations on the effect of substances applied to plants internally, which are to be reported on more fully in a separate publication. Since 1912, Rumbold has been making an extended investigation of tree injections in connection with the chestnut bark disease.[6]

Serums and Toxins.

Another method with theoretical possibilities, but not of much promise practically is the use of serums or viruses made from the products of parasitic fungi in cultures or from the tissues of their parasitized hosts. Beauverie[7] immunized begonias to *Botrytis cinerea* Pers. by planting them in earth long covered with Botrytis.

Potter[8] used a toxin from *Pseudomonas destruans* to stop the growth of this organism on turnips.

Ferraris has a resumé of previous work on internal therapy of plants in Antologia Agraria, 1907, where a more complete bibliography of publications up to that time may be found.

1 Nuov. Giorn. Bot. Ital. 23: 361. 1891.
2 Compt. Rend. 135 : 1067. 1902.
3 Compt. Rend. 135 : 1040. 1902.
4 Zeitschr. Pflanzenkr. 13 : 257. 1903; St. Petersburg Imperial Soc. of Naturalists 1894, and various Russian publications.
5 N. Dak. Exp. Station, Ann. Rept. 13 : 61. 1903; 14 : 55. 1904.
6 Phytopathology 5 : 225. 1915.
7 Compt. Rend. 133 : 107. 1901; see also, Ray, l. c. 307.
8 Journ. Agri. Science 3 : 102. 1908.

Effect of Fertilizers on Corn Diseases.

Some interesting observations on the variation in corn diseases under different fertilizer treatments, not before published, were made at this Experiment Station in 1912 and 1913. It was noticed in a series of plots grown for several years on excess of various fertilizer combinations that in 1912, there was more smut on sweet corn in one plot than the others and a count of all was made with reference to the number of stalks showing smut [*Ustilago zeae* (Beck.) Ung.] and rust (*Puccinia sorghi* Schw.). Next year, the count for smut was repeated and also the relative amount of rot in the ears after picking in the fall was determined. The following table gives the results.

TABLE 1

Fertilizers and Rate Per Acre Annually	1912			1913		
	No. Stalks	No. Stalks with Smut	No. Stalks with Rust	No. Stalks	No. Stalks with Smut	Per cent. Grain Rotted
Dried blood, 1,000 pounds Sulphate potash, 250 pounds Dissolved S. C. rock, 1,000 pounds	104	0	0	113	7	11.0
Dried blood, 1,000 pounds Dissolved S. C. rock, 1,000 pounds	128	6	5	119	7	12.8
Dried blood, 1 000 pounds Sulphate potash, 250 pounds	113	0	5	126	3	13.0
Dissolved S. C. rock, 1,000 pounds Sulphate potash. 250 pounds	156	22	2	118	0	11.6
Nothing	177	8	2	126	7	21.7

The most striking thing to be seen in the above is that the potash-phosphorus plot which was so badly smutted in 1912, was just as notably free from smut in 1913. The plants on the plots with heavy application of phosphate develop faster and are in bloom before the others. The difference in infection might be due to being in a susceptible stage of development at a time when smut conidia were abundant.[1]

Internal Medication of Tomatoes.

Massee[2] reports in 1903, an attempt to immunize tomatoes against *Cladosporium fulvum* Cke. Plants were watered every third day with 1-7,000 copper sulfate solution. Others not so treated were placed among them. After one month, all the treated plants were

1 See Kans. Exp. Station Bul. 62 : 186-187. 1896.
2 Journ. Roy. Hort. Soc. 28 : 142.

free from Cladosporium and some of the check plants had the disease. At this time, all the plants were sprayed with spores of the fungus and the check plants soon became badly diseased. After six weeks, the strength was increased to 1-6,000 and applied every fourth day for eleven weeks. None of the treated plants showed a trace of the disease. A chemical test failed to show the presence of copper in the plants.

Reed[1] found no variation in the amount of Phytophthora blight on tomatoes grown on various fertilizers at Blacksburg, Va., in 1910. No other disease was present that year on the experimental area.

McCue[2] reports very little leaf blight on a tomato plot which received 250 pounds of acid phosphate per acre, while plots receiving nitrogen and potash fertilizers were badly defoliated. The check plots were not badly injured, but were worse than the phosphate plot.

Work on Tomatoes at this Experiment Station.

In the spring of 1907, an experiment was started here by C. P. Close and W. R. Ballard for the purpose of determining whether or not the application of a solution of copper sulfate to the soil of pots in which tomato plants were growing would make the plants more resistant to disease. The following results are reported from Mr. Ballard's notes: "Six plots with ten plants in each plot were treated with the solution. An additional plot was used as a check. The plants were kept in pots and the solution was applied once or twice a week, beginning with 2 cc. per pot and gradually increasing the quantity until the plants had been transplanted to eight-inch pots when 50 cc. was applied to each pot. Varying strengths were used and in the three months that the test was run, the total amount of copper sulfate applied to each pot varied from .0342 grams to 1.75 grams.

The plants were apparently not injured and no doubt a larger quantity could have been applied with no ill effects. No attempt was made to determine how much of the copper sulfate was taken up by the plants, nor what chemical reactions may have taken place in the soil.

An attempt was made to inoculate one plant of each plot with the bacterial wilt, but without success, even on the check plot. One plant in each plot was then sprinkled with an infusion from the leaves of tomato plants badly affected with Septoria. Some of the affected leaves were also placed beneath the plants. The disease

1 Va. Exp. Sta. Bul. 192. 1911.
2 Del. Exp. Sta. Bul. 101 : 18. 1913.

soon attacked the plants and spread rapidly to all the plants in the several plots. There seemed to be no difference in the susceptibility of the plants in any of the plots."

In 1912 and 1913, the writer, with the assistance of Mr. Wm. H. White carried on a series of tests of a large number of different chemicals as to their effect on infection of tomatoes by *Septoria lycopersici* Speg. and *Cladosporium fulvum* Cke. The chemicals were applied in solutions of different proportion in distilled water placed in glass tumblers into which the roots of the young plants extended from paraffined paper pots in which they were transplanted, as shown in Fig. 1. Those used in 1912, were in washed glass sand and in 1913, in rich loam.

FIG 1.

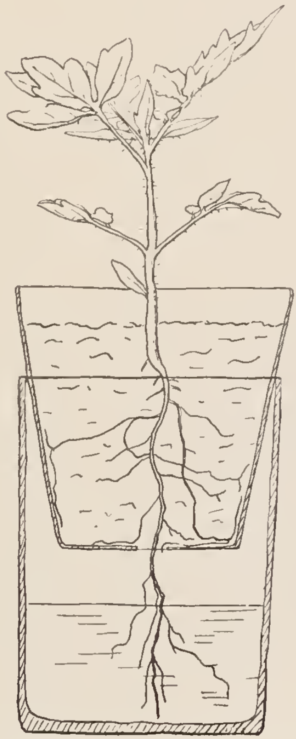

FIGURE 1. Section of glass tumbler and pot showing method of applying chemicals to tomato roots.

In general, four different concentrations, with a distilled water control were used in duplicate for each chemical. One set of each was inoculated with Cladosporium and the other with Septoria obtained

by washing recently diseased leaves in water, into which the plants in the experiment were then dipped.

The device used allowed the solutions studied to come in contact with the roots without being acted upon by the soil, except through the plants. The most uniform results were obtained when a single root came through the hole in the bottom of the pot. If there were more, they often acted as a wick and took up the solution so rapidly as to keep the soil in the pot too wet for favorable growth. A single root would usually take up the solution quite readily. No analyses were made to see whether the substances in solution actually entered the plant, or what selective action the roots had. In most of the tests, the "Green Stem" cherry variety described in Proc. Soc. Hort. Science, 1910:71, was used. The plants were 4 to 6 inches high and had about 6 leaves. The roots were cut off to a uniform length, so that the end just reached the bottom of the tumblers. The plants were kept on greenhouse benches, with the usual greenhouse conditions of temperature and humidity. The glasses had about 200 cc. capacity and about 60 to 100 cc. of solution was used in each.

The Septoria and Cladosporium were selected on account of their abundance and the ease with which plants can be infected with them. Some preliminary tests of infecting tomatoes with *Septoria lycopersici* were made, and it found that the cycle from spore to spore could be completed after inoculation in from 5 to 10 days, depending chiefly upon the temperature; infections being obtained with ease and in abundance under a variety of conditions. However, in the tests with chemicals, we failed to secure infections in a number of cases, even on the checks in distilled water, though every favorable condition that was thought of was given. For this reason, the results with many of the chemicals tried are inconclusive.

As the experiments progressed, there was so little indication of value in reference to increased resistance due to the chemicals used that the work was not carried to completion. It is possible that more careful repetitions might show more decided conclusions. In addition to the disease resistance effects, the results as shown in the following pages are of some value in showing the concentrations of different substances at which injury to tomatoes resulted. This, of course, is much higher than the concentrations necessary to reduce growth.

Summary of Chemicals Used and Results From the Same.

1. *Chemicals showing possible effect on leaf disease development.*

In the following trials, there is shown a variable amount of Sep-

toria or Cladosporium which, in most cases, seems to bear some relation to the concentration acting on the plants. The dates are those on which the cultures were started.

Barium Nitrate. August 12, 1913. Concentrations used: 1-100, 1-200, 1-500, 1-1,000. Slight injury showed after 7 days on the 1-100. In 13 days, Septoria spots were found on all, including the water check plant; 3 spots on the 1-100, 6 spots on the 1-200, 8 spots on the 1-500 and 6 spots on the 1-1,000 cultures.

Calcium Chloride. July 17, 1913. Concentrations used: 1-1,000, 1-1,500, 1-2,000, 1-2,500. None of the plants showed injury, but after 12 days Septoria had developed as follows: None on the 1-1,000, 15 spots on the 1-1,500, 19 spots on the 1-2,000, 19 spots on the 1-2,500, and only 4 spots on the water culture. This substance was used also August 23, 1912 and showed injury after 2 days on concentrations down to 1-1,000, the weakest then used.

Calcium Nitrate. September 12, 1913. Concentrations used: 1-100, 1-200, 1-250, 1-300. After 8 days, the 1-100 plants were dead. A few Septoria spots were found on the 1-200 culture, and the same abundant on the weaker cultures, including the check in water. Calcium nitrate was used July 26, 1913, in the following strengths: 1-50, 1-75, 1-100, 1-150 and showed injury on all in from 2 to 6 days, according to the strength.

Cerium Sulfate. July 18, 1812. Concentrations used: 1-500, 1-1,000, 1-5,000, 1-10,000. Injury showed in 6 days on the two stronger concentrations. Cladosporium developed only on the 1-5,000 cultures. Septoria showed in 2 days on the 2 stronger and later injured cultures also on the check and in 5 days on the other two. These are probably from accidental infections taking place before the test culture was started. Cerium sulfate was also used June 30, 1913, in 1-250, 1-500, 1-750 and 1-1,000 concentrations. In 1 to 2 days the plants in these turned yellow; no leaf fungi developing.

Copper Sulfate. April 13, 1912. Concentrations used: 1-100, 1-1,000, 1-10,000, 1-100,000, 1-1,000,000. Injury showed as dark spots in 2 days on the 1-100. The other plants had turned yellowish in 11 days, but all had developed Septoria, those in the 1-10,000 and 1-100,000 showing more spots than the others.

April 20, 1912. Concentrations used: 1-500, 1-1,000, 1-5,000 1-10,000, 1-50,000 and 1-100,000. In 2 days, the 1-500 plants had turned brown, as also the lower leaves on the 1-1,000 and 1-5,000 cultures. These 3 were all dead in 6 days. After 14 days, 7 Septoria spots had developed on the plant in water; 13 on the 1-50,000 plant; 17 on the 100,000 and 12 on the 1-10,000.

April 27, 1912. Concentrations used: 1-6,000, 1-7,000, 1-8,000,

1-9,000, 1-10,000 and 1-12,000. On May 4, all the plants, except the check in water showed injury. In 6 days, most of the plants were dead and both Septoria and Cladosporium had developed on the remaining ones infected with the same.

June 24, 1912. Concentrations used: 1-500, 1-1,000, 1-5,000, 1-10,000. Injury showed as black spots in the higher concentrations in from 1 to 5 days. No injury developed on 1-10,000 solution, which, with the water culture, developed Cladosporium in 5 days and Septoria in 10 days.

July 28, 1913. Concentrations used: 1-2,000, 1-5,000, 1-7,000 and 1-10,000. Injury resulted on all but the latter, but no leaf fungi developed even on the check.

Dissolved South Carolina Rock Fertilizer. December 17, 1913. Concentrations used: 1-100, 1-200, 1,300 and 1-400. No injury resulted to any. In 10 days, Cladosporium had developed on all, including the check in water, and Septoria had developed only on the control plant, but showed several days later on the 1-400 concentration. This agrees with McCue's statement, that phosphate fertilizers are unfavorable to development of the leaf blight.

Lime Water. July 18, 1912. Concentrations used: 1-0, 1-1, 1-3, 1-7 and 1-15. Injury showed in 4 to 6 days on the 3 higher strengths. Septoria developed on the others in 2 days (from previous accidental infection?) and in 5 days, on the control plant.

July 8, 1913. Concentrations used: 1-7, 1-15, 1-25 and 1-50. No injury resulted on any, but the attempted infections all failed.

Mercuric Chloride. July 31, 1913. Concentrations used: 1-500, 1-1,000, 1-5,000, 1-10,000. In 5 days, the plants on the 1-500 and 1-1,000 concentrations were severely injured. After 10 days, the 1-5,000 plants showed injury, but the Septoria plant had developed a few spots. The 1-10,000 plants showed some injury and developed Septoria in abundance, as also did the water culture.

Morphine Acetate. June 18, 1912. Concentrations used: 1-500, 1-1,000, 1-10,000, 1-100,000. Injury showed in 3 days on the lower leaves of the 1-500 culture, but none on the others. Septoria developed in 6 days on the 1-100,000 and the control in water.

Oxalic Acid. May 3, 1912. Concentrations used: 1-100, 1-200, 1-300 and 1-400. The plants in the 2 stronger showed severe injury at the base in 3 days, but the tops remained green for sometime later. In 7 days, Septoria had developed on all 4 cultures and the water control and Cladosporium on all but the 1-100 and 1-200, which were dead. This was repeated on June 25, 1912, all the plants showing injury at the base in 1 to 2 days, but no infection resulted. On July 28, 1913, oxalic acid was used as follows: 1-400, 1-500, 1-600, 1-700.

Injury showed at the base in 2 to 3 days on all. No infections resulted. This was repeated September 12, 1913, with concentrations down to 1-800. All the plants were dead in 8 days, except the water control, which alone had developed Septoria.

Phloroglucin. August 10, 1912. Concentrations used: 1-200, 1-500, 1-1,000 and 1-5,000. Injury showed next day on all but the last. No infections.

July 19, 1913. Concentrations used: 1-500, 1-1,000, 1-1,500 and 1-2,000. In 2 days, the 1-500 plant was dead, the leaves being a dark brown, and the others showed brown spots at the edges. No infections developed.

September 10, 1913. Concentrations used: 1-2,000, 1-3,000, 1-4,000 and 1-5,000. After 8 days, the 1-2,000 plants were dead, 6 spots of Septoria showed on the 1-3,000, 10 on the 1-4,000 and a large number on the 1-5,000, and 9 on the water check plant. Septoria developed later in abundance on all but the first.

Potassium Nitrate. August 5, 1913. Concentrations used: 1-100, 1-500, 1-1,000 and 1-5,000. The plants on the 1-100 were killed in 3 days, the others survived. No infection appeared.

September 17, 1913. Concentrations used: 1-200, 1-300, 1-400 and 1-500. No injury developed on any. A few spots of Septoria had developed in 6 days on the 3 higher concentrations, and in abundance on the 1-500 and on the water control.

Potassium Permanganate. June 26, 1912. Concentrations used: 1-100, 1-500, 1-1,000 and 1-5,000. Injury showed in 2 days on the first and in 4 days on the second and third. The 1-5,000 developed Septoria in 4 days.

July 8, 1913. Concentrations used: 1-800, 1-1,000, 1-2,000 and 1-5,000. No injury resulted on any. After 13 days, 20 Septoria spots showed on the 1-2,000, 5 spots on the 1-5,000 and 4 spots on the water control. None on the others.

Sodium Acetate. September 17, 1913. Concentrations used: 1-100, 1-150, 1-200 and 1-250. In 5 days, all the plants were dead, except the water control on which Septoria developed in 6 days.

January 24, 1914. Concentrations used: 1-500, 1-600, 1-700, 1-800. No injury resulted. Cladsporium developed on all the plants, but more abundantly on the water control. A few spots of Septoria showed in the 1-500 and 1-700 plants only.

Sodium Nitrate. August 6, 1913. Concentrations used: 1-100, 1-500, 1-1,000, 1-5,000. In 6 days, the plants on the 1-100 strength had died. No others showed injury. A few Septoria spots appeared in 6 days on each of the other cultures, except the plant in water.

Sodium Tungstate. August 10, 1912. Concentrations used: 1-500,

1-1,000, 1-5,000 and 1-10,000. Injury showed next day on the first two. Septoria developed in 5 days on the 1-10,000 and the water cultures.

July 19, 1913. Concentrations used: 1-1,000, 1-2,000, 1-3,000 and 1-4,000. In from 2 to 5 days, injury showed on all but the latter. No infection developed except 6 spots of Septoria in 7 days on the 1-3,000 culture.

September 8, 1913. Concentrations used: 1-2,500, 1-3,000 and 1-4,000. No injury resulted. In 7 days, 10 spots of Septoria showed on the 2 plants in 1-2,500 concentration. Six spots on the 1-3,000, 10 spots on the 1-4,000 and 8 spots on the control in water. In a few days, all were covered with Septoria spots.

2. *Chemicals used without evident effect on leaf parasites.*

With the following cultures with various chemicals, either no infections were secured even on the control plants in water, or the leaf diseases appeared equally on all plants not killed by the chemicals, or infections were so infrequent as to be without value.

Acetone. July 3, 1912. 1-100, 1-500, 1-1,000, 1-10,000. No injury.

Ammonia. August 13, 1913. 1-50, 1-100, 1-200, 1-500. No injury.

Asparagin. August 12, 1912. 1-100, 1-500, 1-1,000. The first showed injury in 2 days.

July 21, 1913. 1-50, 1-75, 1-100, 1-200. Plants wilted in 2 to 3 days in all except the latter and in the water check.

Barium Chloride. August 12, 1912. 1-500, 1-1,000, 1-10,000, 1-100,000. Injury to the first two in 1½ days.

July 26, 1913. 1-1,000, 1-1,500, 1-2,000, 1-5,000. No injury.

September 10, 1913. 1-500, 1-1,000, 1-1,500, 1-2,000. No injury to any. Septoria developed equally on all, or a little less at first on the stronger concentrations.

Barium Oxide. August 23, 1912. 1-100, 1-500, 1-1,000, 1-10,000. Injury on the first in 1 day.

July 17, 1913. 1-100, 1-150, 1-200, 1-400. In 4 days, plants on first dead, one dead and one turning yellow on the 1-150, the others showed no injury.

September 5, 1913. 1-150, 1-200, 1-300, 1-400. Plants on the 1-150 dead in 3 days, no injury on the others. Septoria developed equally on all that lived.

Carbolic Acid. July 18, 1912. 1-100, 1-500, 1-1,000, 1-10,000. The plants on 1-100 had the stem turned black in one-half day, the 1-500 the same in 1 day, the 1-1,000 in 2 days, the 1-10,000 remained healthy.

June 30, 1913. 1-250, 1-500, 1-750, 1-1,000. Black spots appeared on the leaves of all but the latter in 1 day.

Cedar Oil. July 3, 1912. 1-50, 1-100, 1-500. The base of the stem in all 3 was killed and shrunken in 5 days.

Chromic Acid. August 13, 1913. 1-100, 1-200, 1-500, 1-1,000. All killed in 1 day.

September 24, 1914. 1-1,000, 1-2,000, 1-3,000, 1-4,000. In 4 days all were dead.

Chloral Hydrate. June 25, 1912. 1-200, 1-500, 1-1,000, 1-5,000. The 1-200 showed injury in 5 days; none on the others. Septoria developed on the 1-5,000.

June 30, 1913. 1-150, 1-200, 1-500, 1-1,000. The first two showed injury in 2 days.

Cyanin. August 3, 1912. 1-200, 1-1,000, 1-10,000, 1-50,000. Injury showed on the 1-200 in 1 day, on 1-1,000 in 5 days, 1-10,000 in 6 days.

July 15, 1913. 1-10,000, 1-15,000, 1-20,000, 1-30,000. On the fifth day, all except the weakest solution showed yellow leaves but in 10 days, only the 1-10,000 had died.

Eosin. July 1, 1912. 1-1,000, 1-10,000, 1-100,000, 1-1,000,000. The plants all wilted down in from 1 to 3 days exeept in the weakest eoncentration.

Formaldehyde (40%). July 25, 1912. 1-50, 1-100, 1-500, 1-1,000. All wilted in 1 to 2 days.

July 8, 1913. 1-100, 1-500, 1-750, 1-1,000. All showed brown spots in the leaves in 1 to 2 days.

September 5, 1913. 1-750, 1-1,000, 1-1,500, 1-2,000. Plants died in 3 to 6 days.

March 11, 1914. 1-2,000, 1-2,500, 1-3,000, 1-4,000. Injury at the base showed on the 1-2,000 in two days and in 1-2,500 in 3 days. No injury on the others.

Glucose. July 25, 1912. 1-50, 1-100, 1-500, 1-1,000. Injury showed on 1-50 in 2 days and on 1-100 in 4 days, none on the others. Septoria developed only on 1-1,000, none on the control in water.

Hydrogen Peroxide (*Dioxygen*). August 23, 1912. 1-50, 1-100, 1-500, 1-1,000. No injury.

August 1, 1913. The same repeated. No injury. Septoria developed abundantly on all.

Mareh 11, 1914. 1-1, 1-5, 1-10, 1-20. The leaves were slightly yellow on the 1-1 on the third day. The next day, the 1-5 was turning yellow and the 1-1 had yellowed deeidedly. No other effeet was observed.

Iodine Green. July 2, 1912. 1-500, 1-1,000, 1-10,000, 1-100,000. Next day, the stems in 1-500 were blue; the seeond day these and those in 1-1,000 were wilted. In 6 days, all were dead.

Iron Sulfate. August 3, 1912. 1-50, 1-100, 1-500, 1-1,000, 1-5,000. The two higher concentrations injured the plants in 1 day; the 1-500 in 5 days.

July 15, 1913. 1-500, 1-600, 1-800, 1-1,000. All the plants showed yellow spots in 5 days, but only the 1-500 died.

December 17, 1913. 1-50, 1-100, 1-200, 1-500. All the plants died in 3 to 6 days, according to the concentration.

December 27, 1913. 1-600, 1-700, 1-800, 1-1,000. In 5 days, the plants on the two higher concentrations were turning brown and in 10 days, these and the next lower were dead. Those on 1-1,000 were slightly yellow in 10 days, but had developed some Septoria and Cladosporium, as had the check in water.

Kerosene. July 3, 1912. 1-50, 1-100, 1-500. The plants in 1-50 and 1-100 wilted in 1 day; in 5 days, all were dead.

Lead Acetate. July 31, 1913. 1-500, 1-1,000, 1-5,000, 1-10,000. In 8 days, the first two were dead. The others remained uninjured and developed Septoria abundantly, as did also the control in water.

Magnesium Sulfate. July 26, 1912. 1-100, 1-500, 1-1,000, 1-5,000. Injury showed on the first in 4 days, at which time Septoria showed on 1-500. No further injury or diseases developed.

July 9, 1913. 1-500, 1-600, 1-700, 1-1,000. No injury or leaf disease developed.

Potassium Ferro-cyanide. June 18, 1912. 1-500, 1-1,000, 1-10,000, 1-100,000. The plants in 1-500 strength died in 1 day. The next showed injury in 4 days. The others developed Cladosporium and Septoria in 6 days, but no further injury showed.

June 26, 1913. 1-700, 1-1,000, 1-5,000, 1-10,000. Injury showed around the edges of the leaves in 1 to 2 days on all but the latter.

Potassium Iodide. May 3, 1912. 1-100, 1-500, 1-1,000, 1-5,000, 1-10,000. In 6 days, the plants in the 2 higher concentrations were dead and the lower leaves had fallen from the others. Septoria and Cladosporium developed on all except those which died.

June 25, 1912. 1-250, 1-500, 1-750, 1-1,000, 1-5,000. Injury showed on the first two in 3 to 5 days.

Potassium Hydroxide. July 1, 1912. 1-100, 1-500, 1-1,000, 1-5,000. The plants wilted and died in 1 to 3 days, according to the concentration.

Potassium Chloride. August 2, 1913. 1-100, 1-500, 1-1,000, 1-5,000. In 3 days, one of the plants on 1-500 was dead. No further effect was noticed.

Potassium Chromate. August 12, 1913. 1-100, 1-200, 1-500, 1-1,000. All dead in 2 days.

September 26, 1913. 1-1,000, 1-2,000, 1-3,000, 1-4,000. All dead in 4 days.

December 27, 1913. 1-5,000, 1-10,000, 1-50,000, 1-100,000. Both plants on 1-5,000 dead in 3 days. Cladosporium developed on those infected with it. A few Septoria spots developed on the 1-50,000, more on the 1-100,000, and also on the check.

Sulfur. July 1, 1912. 1-10, 1-25, 1-50, 1-100. No injury or leaf disease showed.

August 6, 1913. 1-50, 1-100, 1-200, 1-500. Both plants on 1-50 dead in 6 days; no other effect observed.

Sulfuric Acid. July 1, 1912. 1-100, 1-500, 1-1,000. All died in 1 to 2 days.

Sodium Nitro-prusside. August 12, 1912. 1-500, 1-1,000, 1-10,000, 1-50,000. The first two killed in one-half to 1 day. The others not injured and developed Septoria in 5 days, including the water control plant.

July 21, 1913. 1-1,000, 1-1,500, 1-2,000, 1-2,500. The plants on 1-1,000 browned on the edges in 1 day and in 2 days had wilted down. The 1-1,500 plants showed slight injury the first day, but in 2 days wilted down. The others showed slight injury in 3 to 5 days.

Strychnine Sulfate. June 18, 1912. 1-500, 1-1,000, 1-10,000, 1-100,000. The leaves on the 1-500 turned yellow in 1 day and in 4 days all but the youngest leaves were dead and brown. None of the others showed injury. Septoria developed only on the 1-10,000.

June 30, 1913. 1-700, 1-1,000, 1-5,000, 1-10,000. Injury developed on the first two in 2 days.

Thymol. August 23, 1912. 1-200, 1-500, 1-1,000. All injured in 2 days.

Summary.

In most cases where Septoria or Cladosporium growth was secured on the control plants in distilled water and in the lower concentrations of the chemicals tested, the higher concentrations killed or injured the plants before the fungi could develop. In a few instances, there is some indication that concentrations lower than those causing injury may have reduced the development of the leaf parasites more than on the controls. This is shown with potassium nitrate, sodium acetate, morphine sulfate, calcium nitrate, copper sulfate, lime water, sodium tungstate and potassium permanganate. In some cases, the Cladosporium seemed to develop on concentrations higher than the Septoria. This is quite marked in case of acid phosphate.

On mercuric chloride, sodium nitrate, barium nitrate, cerium sulfate and notably on oxalic acid, Septoria developed even on plants showing injury from the chemicals.

The concentrations that tomatoes will stand without injury was determined for about 50 chemicals.

Conclusions.[1]

1. Some previous investigations have shown increased resistance to leaf diseases in various plants after the application of certain chemicals through the stem or to the roots. Others have obtained negative results.

2. In the experiments here recorded, tomato plants to whose roots various chemicals in different strengths were applied, in some cases developed less leaf disease (in the case of *Septoria lycopersici* in particular) on the higher concentrations, where these were not strong enough to cause injury, than on the lower concentrations or in water. In general, the results were negative.

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[1] A more promising line of attack against *Septoria lycopersici* lies in the natural resistance, which a series of investigations now in progress has shown to be quite varied in the seedlings of different varieties. These vary both in the rapidity of development of the fungus in the leaves and in the number of disease spots produced. The dwarf varieties are especially susceptible to Septoria.

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TESTS OF THE AVAILABILITY OF DIFFERENT GRADES OF GROUND LIMESTONE.

By L. B. Broughton, R. C. Williams and G. S. Frazee.

How Fine Should Limestone and Oyster Shells be Ground for Use on Soils?

The investigation of the problem was begun in order to determine the fineness of material that should be used for liming soils when ground limestone and oyster shells are employed. This question arose from recommendations that had been given by some soil experts advising that farmers could use crushed limestone ranging in size of particles from the finest pulverized to that of a very coarse grade. These recommendations are based upon the assumption that the lasting qualities of the lime will depend largely upon its grade of fineness, the larger particles being less soluble, therefore will not be leached or lost so quickly from the soil. In other words, the farmer can, by applying a number of tons of rather coarse material, have its effect remain for a long number of years.

Review.

There is little exact experimental evidence bearing on this subject, but those who have used the coarse material such as used for road ballast have observed marked improvement in some instances. However this improvement may have been due to the fine material that is always found after grinding any limestone. Authors differ in their conclusions. The Massachusetts[1] station recommends the use of limestone pulverized so that it will pass a 75 mesh sieve, whereas the Michigan[2] station recommends that it shall pass an 80 mesh sieve. The Pennsylvania[3] station concludes, "that on silty loams and on soils of heavier texture, on lands where soil acidity is the chief factor limiting clover production, crushed limestone used for amendment

[1] Mass. Agricultural Experiment Station Bulletin 137, P. S.
[2] Mich. Agricultural Experiment Circular 11, 1911, P. 80.
[3] Penn. State College annual report, P. 214.

should be at least 60 mesh in fineness of pulverization.'' The Rhode Island[4] station, states that as a general rule it would probably take from 200 to 300 pounds of limestone depending on its fineness, to produce the same effect the first season as 100 pounds of freshly slacked lime.

Hopkins, on the other hand, recommends the coarse material as equally valuable as the fine. Baker[5] and Collison say, ''If enough 10 mesh limestone is used to last for three years it will, without question, give fully as good results the first year as a somewhat smaller amount of extremely fine material. Again, Bernard[6] who studied extensively the effect of calcium carbonate in French soils on vineyards, says: ''We cannot too often repeat that the action of lime depends more than anything else upon its degree of fineness. R. Heinrich[7] with pot experiments in growing peas and alfalfa compared the effect of marble sifted to different degrees of fineness in amounts equal to .5 per cent. of the weight of the soil. The carbonate in grains of .06 to .08 inches diameter produced in the case of peas an increase equal to only 19.6 parts of the maximum crop, while the carbonate of .02 to .04 inches produced an increase of 43.1 parts. In the case of alfalfa, the coarser material enabled the plants to survive in the acid, it is true, but gave only three-fifths the crops obtained with material twice as finely pulverized. H. V. Feilitzen[8] in a peat of a low lime content applying large amounts of fertilizer tested lime and limestone of different degrees of fineness and reported in the case of both slacked lime and pulverized limestone increases as the fineness of material increased.

In view of the small amount of exact data, and the conflicting views of some writers, it has been thought desirable to make a study with the idea of determining what grade of fineness of the ground stone is most lasting and yet gives the soil a sufficient amount of soluble calcium for its improvement. To this end the following points have been investigated.

First—The solubility of different grades of fineness of limestone and oyster shells in water and water charged with carbon dioxide.

Second—The solubility of the different grades in a soil solution.

Third—The effect of the different sizes of ground limestone and oyster shells on the growing crop.

Selection of Material.

In selecting the material for this study an effort was made to secure samples of limestone and oyster shells varying in their degrees of

4 Extension News Service Vol. 1, No. 6, R. I. Experiment Station.
5 N. Y. Agricultural Experiment Station Bulletin 400, P. 162

fineness as far as possible. Sample No. 1, as shown in tables No. 1 and 2, is a West Virginia marl and was used as it was taken from the field. The sample is very nearly a pure carbonate of calcium. Samples No. 2 to 5, inclusive, are miscellaneous samples of ground stone secured from the various lime dealers of the State, sample No. 4 being of a dolomitic nature containing a large percentage of magnesium. Samples No. 6 to 9, inclusive, are miscellaneous samples of oyster shells. Samples No. 10, 11 and 12 are specially prepared samples of limestone made from the same lot of stone. Samples No. 13, 14 and 15 are specially prepared samples of oyster shells made from the same lot of shells.

The following tables, No. 1 and 2, give the mechanical and chemical analysis, the samples being arranged in groups according to their degree of fineness, sample No. 1 being the finest ground of all the grades.

In making the mechanical analysis eight sieves ranging in size from 10 to 80 meshes to the linear inch were used. The percentages show the amount that passed the sieve but would not pass the next one in the series.

TABLE No. 1—Mechanical Analysis

Sample Number	10%	20%	30%	40%	50%	60%	70%	80%
MARL 1								
1	....	....	....	....	....	16.93	44.80	38.22
GROUND LIMESTONE								
2	....	....	....	9.10	16.90	4.00	17.74	51.54
3	....	....	....	33.56	41.80	3.54	13.50	7.58
4	....	....	10.54	36.56	33.08	6.54	14.51	4.68
5	34.29	27.14	....	13.28	3.24	....	6.50	15.53
GROUND OYSTER SHELLS								
6	....	....	....	17.54	29.02	....	48.73	4.77
7	....	27.84	1.80	14.36	23.84	2.10	28.25	1.78
8	....	47.08	2.06	9.69	14.59	5.95	16.42	2.02
9	....	72.24	3.44	4.73	9.65	....	6.33	3.69
GROUND STONE SPECIALLY PREPARED								
10	....	....	....	1.02	7.76	11.35	37.20	42.64
11	....	....	....	5.53	38.20	14.60	19.95	21.71
12	14.57	6.25	9.50	22.14	17.98	5.51	7.68	17.34
GROUND SHELLS SPECIALLY PREPARED								
13	....	....	....	1.19	30.18	15.74	39.42	12.78
14	.18	....	.08	30.11	47.74	8.75	9.25	3.86
15	.32	....	27.80	70.51	.59	.09	.30	.14

TABLE No. 2—Chemical Analysis

Sample Number	% SiO_2	% Fe_2O_3 and Al_2O_3	% CaO	% MgO	% *CO_2	% Total
MARL 1						
1	1.12	.35	48.13	.74	49.66	100.00
GROUND LIMESTONE						
2	1.90	5.90	49.12	1.29	41.79	100.00
3	27.94	.80	40.85	.80	29.61	100.00
4	3.10	2.44	46.78	20.44	27.24	100.00
5	2.16	6.90	49.37	1.07	40.50	100.00
GROUND OYSTER SHELLS						
6	9.48	5.60	44.86	.40	39.66	100.00
7	8.10	1.40	49.89	.72	39.66	100.00
8	5.10	.60	51.15	.34	42.81	100.00
9	4.70	.50	52.08	.63	42.09	100.00
GROUND STONE SPECIALLY PREPARED						
10	4.50	3.00	52.85	.60	39.05	100.00
11	2.82	.92	52.81	1.14	42.31	100.00
12	4.90	4.70	51.10	1.02	38.28	100.00
GROUND SHELLS SPECIALLY PREPARED						
13	9.00	2.40	47.88	.70	40.02	100.00
14	5.40	2.00	46.03	.80	45.77	100.00
15	3.96	1.80	48.82	1.37	43.05	100.00

*CO_2 by difference.

The Solubility of the Samples in Water and Water Charged With Carbon Dioxide at 3° C., 12° C., 14° C. and 23° C.

For this experiment water and water charged with carbon dioxide were selected as representing the two main solutions found in a soil. The temperatures represent the average temperatures of the four seasons of the year recorded at this station for the year 1913, 3° C., winter; 12° C., spring; 14° C., autumn; 23° C., summer.

For the determination, 10 grams of the sample was placed in a 500 cc. graduated flask; the solvent at the desired temperature added and made up to mark; the flask and contents placed in a bath at the desired temperature and allowed to remain for one hour with shaking every five minutes; the flask removed and the solution immediately filtered; and aliquot taken and the calcium determined.

The results as given in Table No. 3 show the percentage of soluble calcium oxide (CaO) calculated from the total grams of CaO in 10 grams of the sample used.

TABLE No. 3

Sample	Water				Water Charged with Carbon Dioxide			
	3°C	12°C	14°C	23°C	3°C	12°C	14°C	23°C
MARL 1								
1	1.27	2.49	2.51	3.98	4.21	4.28	4.57	4.61
GROUND LIMESTONE								
2	1.033	1.446	2.086	2.502	2.044	2.958	3.191	3.616
3	.875	1.344	1.419	1.530	1.975	2.484	3.165	3.421
4	.410	1.110	1.186	1.347	1.934	1.966	2.276	2.610
5	.427	.648	1.079	1.083	.912	1.186	1.913	2.276
GROUND OYSTER SHELLS								
6	.752	1.403	1.483	2.004	2.084	3.232	3.500	4.414
7	.713	1.118	1.148	1.237	1.920	2.225	3.034	3.168
8	.537	.912	1.113	1.118	1.212	2.151	2.115	2.465
9	.351	.635	.635	.801	.966	.997	1.026	1.681
SPECIALLY PREPARED LIMESTONE								
10	1.720	2.667	2.840	4.150	1.932	4.126	4.618	5.292
11	1.410	2.779	2.857	3.948	1.928	4.545	4.677	4.952
12	.520	.520	.823	.899	1.115	3.728	3.738	4.172
SPECIALLY PREPARED OYSTER SHELLS								
13	.649	2.760	2.960	4.280	2.040	3.800	3.860	4.670
14	.573	2.620	2.838	3.425	1.980	2.410	2.477	2.696
15	.434	2.236	2.297	2.765	1.252	1.517	1.990	1.989

That the size of the material does effect the solubility of calcium carbonate both as ground limestone and ground oyster shells at all seasons of the year is readily shown by a consideration of the results in the above table. Sample No. 1, a pure marl deposit and a material all of which passed a 60 mesh sieve, being more soluble in water and a carbon dioxide solution than any of the coarser materials. Samples 2 to 5, inclusive, a miscellaneous collection of ground limestone, shows that as the samples increase in size of particles they become less soluble, as is shown by samples 6 to 9, inclusive, which are a collection of miscellaneous samples of ground oyster shells. This fact, however, is brought out more clearly by samples 10-11-12 and samples 13-14-15. The material from which these samples were taken was especially prepared, samples 10-11-12 being taken from the same lot of stone ground to three different degrees of fineness; samples 13-14-15, being oyster shells, all of which were taken from the same lot of shells ground to three grades of fineness. In this connection the most striking results are brought out by samples 12 and 15. From the results on samples 10-11 and 13-14, we would not be justified in saying that ground limestone was more soluble than ground oyster shells,

for a study of their mechanical analysis shows these samples to be made up of about the same size of material, and Table 3 shows their solubility to be about the same, or what would be expected from the different grades. Samples 12 and 15, however, present a much wider range mechanically, sample 15 being made up of material, 90 per cent. of which would not pass a 50 mesh sieve, whereas sample 12 consists of small percentages of all sizes. The solubility of these two samples is very plainly *inferior* to sample No. 12, the finer of the two. Samples 13-14-15, especially prepared oyster shells in which we find a wide range in mechanical parts, as a group presents some very positive results that show the effect of the size of particles, the solubility and mechanical ingredients varying in order of 13-14-15.

Solubility of the Samples in a Soil Solution.

For this determination, large stone pots, glazed inside and outside, having an outlet one-half inch in diameter on the side, one-half inch from the bottom, were used. All pots were of uniform type, each being 13 inches in diameter and 16 inches high. Each pot was filled with 40,000 grams of loam soil, which in turn was treated with the different size ground limestone and ground oyster shells at the rate of 10,000 pounds per acre, calculated on the basis of the first six inches of soil, giving a total of 56 grams of material added to each pot. All pots were placed under artificial conditions, each receiving 88,925 cc. of distilled water, added as per a standard year at this Station.

The experiment was divided into six periods of one month each, each period representing two months of rainfall.

In all, there were sixteen pots used, No. 1 and 2 being check pots. No. 1* was treated with calcium oxide and No. 2* with ground limestone, 90 per cent of which passed an 80 mesh sieve. Pots 3 to 16, inclusive, were treated with samples No. 2 to 16, respectively.

The following tables, No. 4-5-6, give the results of the solubility of the different grades of material arranged in groups according to size of particles.

* Results taken from Bulletin 166 of this Station.

TABLE No. 4

		1	2	3	4	5	6
POT No.		1	2	3	4	5	6
SOIL USED		Loam	Loam	Loam	Loam	Loam	Loam
SAMPLE No.				2	3	4	5
LIME ADDED		Lime (CaO)	Lime-stone $CaCO_3$	Lime-stone $CaCO_3$	Lime-stone $CaCO_3$	Lime-stone $CaCO_3$	Lime-stone $CaCO_3$
Periods	Weight of lime added in grams of CaO	33.39	33.39	27.50	27.64	26.19	22.77
First	c. c. of water added	7380	7380	14380	14380	14380	14380
	c. c. of water collected	0000	0000	5000	5500	5200	5900
	Wt. of CaO in drainage	.0000	.0000	.1200	.1975	.1099	.1229
Second	c. c. of water added	16760	16760	12380	12380	12380	12380
	c. c. of water collected	8300	8000	10500	10500	10500	10500
	Wt. of CaO in drainage	.2100	.2740	.1070	.2086	.2021	.1811
Third	c. c. of water added	10000	10000	20760	20760	20760	20760
	c. c. of water collected	7200	5600	14000	14350	14000	13500
	Wt. of CaO in drainage	.2312	.12875	.5180	.2333	.2362	.2497
Fourth	c. c. of water added	18700	18700	14800	14800	14800	14800
	c. c. of water collected	3800	3700	8750	8000	8500	9250
	Wt. of CaO in drainage	.2500	.1812	.1487	.2040	.1249	.1267
Fifth	c. c. of water added	14750	14750	15225	15225	15225	15225
	c. c. of water collected	700	1950	9500	10250	9250	10000
	Wt. of CaO in drainage	.0500	.2875	.5330	.0867	.1160	.0937
Sixth	c. c. of water added	16845	16845	11380	11380	11380	11380
	c. c. of water collected	6200	5600	4250	3750	3500	3000
	Wt. of CaO in drainage	1.3062	1.9125	.0279	.0158	.0122	.0077
Total c. c. of water added for year		84425	84425	88925	88925	88925	88925
Total c. c. of water collected for year		26200	24900	52000	52600	51200	52150
Total weight of CaO removed in drainage water		2.0474	2.9427	1.0749	.9459	.8013	.7818
Per cent. of lime removed through drainage		6.13%	8.51%	3.90%	3.42%	3.05%	3.43%

TABLE No. 5

POT No.		7	8	9	10
SOIL USED		Loam	Loam	Loam	Loam
SAMPLE No.		6	7	8	9
LIME ADDED		Ground Oyster Shells $CaCO_3$	Ground Oyster Shells $CaCO_3$	Ground Oyster Shells $CaCO_3$	Ground Oyster Shells $CaCO_3$
Periods	Weight of lime added in grams of CaO	25.12	28.64	29.16	27.93
First	c. c. of water added	14380	14380	14380	14380
	c. c. of water collected	5900	4800	6250	5000
	Wt. of CaO in drainage	.2566	.1008	.1421	.1187
Second	c. c. of water added	12380	12380	12380	12380
	c. c. of water collected	9750	10000	10500	10500
	Wt. of CaO in drainage	.1404	.2375	.1417	.2152
Third	c. c. of water added	20760	20760	20760	20760
	c. c. of water collected	14000	14000	13500	12500
	Wt. of CaO in drainage	.3552	.3097	.3375	.2140
Fourth	c. c. of water added	14800	14800	14800	14800
	c. c. of water collected	8750	7500	7750	8750
	Wt. of CaO in drainage	.1618	.0975	.1472	.1257
Fifth	c. c. of water added	15250	15250	15250	15250
	c. c. of water collected	10000	10500	10000	10500
	Wt. of CaO in drainage	.1900	.1586	.1512	.1261
Sixth	c. c. of water added	11380	11380	11380	11380
	c. c. of water collected	3250	3500	4100	4000
	Wt. of CaO in drainage	.0307	.0196	.0238	.0184
Total c. c. of water added for year		88925	88925	88925	88925
Total c. c. of water collected for year		51900	50300	52100	50500
Total wt. of CaO removed in drainage water		1.1347	.9237	.9436	.8181
Per cent. of lime removed through drainage		4.51%	3.22%	3.23%	2.95%

TABLE No. 6

POT No.		11	12	13	14	15	16
SOIL USED		Loam	Loam	Loam	Loam	Loam	Loam
SAMPLE No.		10	11	12	13	14	15
LIME ADDED		Limestone $CaCO_3$	Limestone $CaCO_3$	Limestone $CaCO_3$	Ground Oyster Shells $CaCO_3$	Ground Oyster Shells $CaCO_3$	Ground Oyster Shells $CaCO_3$
Periods	Weight of lime added in grams of CaO	29.41	29.59	28.61	25.77	26.81	27.33
First	c. c. of water added	14380	14380	14380	14380	14380	14380
	c. c. of water collected	5200	5000	5700	6800	5100	5000
	Wt. of CaO in drainage	.1072	.0987	.0900	.1769	.1179	.0975
Second	c. c. of water added	12380	12380	12380	12380	12380	12380
	c. c. of water collected	9250	10200	10500	10500	10200	10000
	Wt. of CaO in drainage	.2081	.2882	.2500	.2979	.2306	.1775
Third	c. c. of water added	20760	20760	20760	20760	20760	20760
	c. c. of water collected	14000	11500	14000	14000	14000	13500
	Wt. of CaO in drainage	.3167	.1710	.2000	.2817	.2507	.1586
Fourth	c. c. of water added	14800	14800	14800	14800	14800	14800
	c. c. of water collected	7500	8750	9750	9000	9000	8250
	Wt. of CaO in drainage	.1631	.1428	.1468	.1968	.1541	.1639
Fifth	c. c. of water added	15225	15225	15225	15225	15225	15225
	c. c. of water collected	10500	10500	10500	10500	10500	9750
	Wt. of CaO in drainage	.1378	.1326	.1000	.1251	.1391	.1128
Sixth	c. c. of water added	11380	11380	11380	11380	11380	11380
	c. c. of water collected	4000	3500	4000	4500	4000	3250
	Wt. of CaO in drainage	.0214	.0204	.0230	.0258	.0230	.0149
Total c. c. of water added for year		88925	88925	88925	88925	88925	88925
Total c. c. of water collected for year		50450	49450	54500	53300	52800	49750
Total weight of CaO removed in drainage water		.9543	.8537	.8098	1.0942	.9154	.7252
Per cent. of lime removed through drainage		3.21%	2.90%	2.82%	4.24%	3 41%	2.65%

From the data collected on the solubility of the different grades in a soil solution, it is very positively shown that some factor has been introduced that controls the solubility of these materials to a marked degree.

Taking as a standard of fineness calcium oxide, the results of which are shown in Table 4, pot 1, and comparing these results with pot 2, which was treated with very finely ground limestone, it is found that the carbonate in this finely divided state is as soluble or in fact more soluble than that of the oxide. Using pot No. 2 as a standard and comparing the other carbonates with this one, it is readily seen, Table 4, that sample 2, pot 3, the finest of all the carbonates in this lot, but not as fine as that of pot 2, is much less soluble than the very fine carbonate, and, in fact, as the size of particles increase, as in pots 4-5-6 there is a smaller percentage of soluble CaO found in the soil water.

Table 5, which gives the results of a similar experiment with ground oyster shells in the same soil, shows very conclusively that the size of particles influence the solubility of this material, when it is used as a lime for soils. Pot No. 7 treated with sample No. 6, which contains over 50 per cent. of fine material that passed a 70 mesh sieve, is just a little more than half as soluble as the carbonate in pot No. 2 or the very finely ground limestone, and it is readily seen that as the samples increase in size of particles as they do in pots 8-9-10, that the soluble calcium oxide becomes less.

Table 6 gives the results of the two lots of specially prepared limestone and oyster shells. Pots 11-12-13 treated with samples 10-11-12, three samples of limestone taken from the same lot of stone, and pots 14-15-16 treated with samples 13-14-15, oyster shells prepared from the same lot of shells, show that the variation in solubility is not due to the individuality of the samples; the finer the material the more soluble calcium found in the soil water.

Theoretical Considerations.

From the data presented in the preceding pages, it is shown that the solubility of the different grades of fineness of limestone and oyster shells, in solutions representing in part those of a soil, and in a soil solution, that the amount of available calcium depends to a very marked degree on the size of particles that are used.

Using the solubility of calcium oxide in a soil solution as a standard, an unusual amount of coarsely ground stone would be required to give to the soil the same amount of calcium, as from the above results, 10,000 pounds of samples 2-10-13, all of which passed a 10 mesh sieve, but less than half would pass an 80 mesh sieve, failed to supply but little more than one-half as much soluble calcium as 4,000 pounds of calcium oxide.

In liming a soil it is desirable that the neutralizing effects of a limestone shall be felt within a few weeks after the limestone has been applied. The quantity of carbonate of lime that any soil water can hold cannot be altered, but the rate of supply can be influenced. All things being equal, the greater the surface of the material to be dissolved, the greater the solubility. The finer the material used, the more rapidly will it be attacked and taken into solution. Thus, a ton of limestone ground to pass an 80 mesh sieve presents a surface eight times as great as a ton of the same material ground to pass a 10 mesh sieve.

Thus for these reasons, the finer a limestone is ground, the quicker it will have the desired effect in neutralizing soil acidity and increasing crop production.

The Effect of Different Quantities of Lime and Different Degrees of Fineness of Ground Limestone and Ground Oyster Shells on Crop Production.

With the idea of determining the effect of different kinds and grades of lime and also their lasting qualities this study was begun in the summer of 1914; the samples being of the same general type as those discussed in the preceding pages; the study in the main being built around the specially prepared limestone and oyster shells; the grades of each being prepared from the same lot of stone and shells.

The soil being used for this work is a sandy loam that has not been under cultivation for a number of years and no lime has ever been added as far as is known. The plots are of 1/20 acre and with the exception of the amount and kind of lime added, are being treated in exactly the same way. So far, no commercial fertilizer has been added except on the wheat plots.

Plots 1 to 15, inclusive, were limed October 21, 1914, and sown to wheat on October 22, 1914. The wheat was harvested in the summer of 1915 and the plots will be sown to crimson clover in the fall and turned under for corn in the spring of 1916.

Plots 16 to 27, inclusive, were limed October 8, 1914, and sown to wheat on October 10, 1914. The wheat on these plots was winter killed, the plots plowed in the spring and planted to mixed cow peas on June 15, 1915, to be plowed under for wheat in the fall.

Plot 28, marl added June 8, 1915, same planted to mixed cow peas on June 15, 1915, to be plowed under for wheat.

Plots 29 to 34, inclusive, sown to crimson clover in August, 1914, clover winter killed. Plots were limed May 22, 1915, same planted to corn June 11, 1915.

Plots 35-36-37, marl put on June 8, 1915. Planted to corn June 11, 1915.

The following table gives the plot number with the material and amounts of same used:

TABLE No. 7.

No. Plot	Material Used.	Pounds. per Acre.
1	Check	No lime
2	Ground oyster shells	7120
3	Ground limestone	7120
4	Burnt limestone	4000
5	Burnt lime (oyster shells)	4000
6	Ground oyster shells	3560
7	Ground limestone	3560
8	Check	No lime
9	Burnt limestone	2000
10	Burnt lime (oyster shells)	2000
11	Ground oyster shells	1780
12	Ground limestone	1780
13	Burnt limestone	1000
14	Burnt lime (oyster shells)	1000
15	Check	No lime
16	Fine ground stone (No. 1 stone)	10000
17	Fine ground shells (No. 1 shells)	10000
18	Medium ground stone (No. 2 stone)	10000
19	Medium ground shells (No. 2 shells)	10000
20	Coarse ground stone (No. 3 stone)	10000
21	Coarse ground shells (No. 3 shells)	10000
22	Fine ground stone (No. 1 stone)	5000
23	Fine ground shells (No. 1 shells)	5000
24	Medium ground stone (No. 2 stone)	5000
25	Medium ground shells (No. 2 shells)	5000
26	Coarse ground stone (No. 3 stone)	5000
27	Coarse ground shells (No. 3 shells)	5000
28	Fine ground marl	5000
29	Fine ground stone (No. 1 stone)	10000
30	Fine ground shells (No. 1 shells)	10000
31	Medium ground stone (No. 2 stone)	10000
32	Medium ground shells (No. 2 shells)	10000
33	Coarse ground stone (No. 3 stone)	10000
34	Coarse ground shells (No. 3 shells)	10000
35	Fine ground marl	10000
36	Fine ground marl	3600
37	Fine ground marl	1800

The material used on plots 1-6-11 and 2-7-12 is finely ground limestone and oyster shells taken from the same lot of stone and shells. Plots 4-9-13 and 5-10-14 were limed with different amounts of stone lime and oyster shell lime. Plots 16-22-29 and 17-23-30 were treated with the same size material of ground stone and shells of the very finest grade. Plots 18-25-31 and 19-26-32 were limed with a coarser material made from the same lot of stone and shells as plots 16-22-29 and 17-23-30 are limed with. Plots 20-26-33 and 21-27-34 are treated with a very coarse material made from the same lot of stone and shells.

It is greatly regretted that results on the preceding outline cannot be given out at the present time, it being felt that sufficient data has not been collected to formulate a definite conclusion.

*However, some results secured at the Rhode Island Experiment Station and the Pennsylvania Experiment Station should prove of interest in connection with the often asked question: How fine should limestone be ground?

At the Rhode Island Station the same amount of calcium oxide (actual lime) was added to each plot to be considered, and the different forms all came from the same original stone. The lime was applied in the spring of 1913. A large amount of complete fertilizer was added in both 1913 and 1914.

Of the results obtained with different crops, the following pounds of roots seem best to illustrate the comparative effect of a given amount of lime on the different forms.

	Mangels 1913	*Carrots 1914*
No lime	107	175
Limestone siftings (10-20 mesh)	138	314
Limestone siftings (20-40 mesh)	204	469
Limestone siftings (40-80 mesh)	280	480
Limestone siftings (finer than 80 mesh)	389	563
Limestone, unsifted	279	470
Slacked lime [Ca(OH)2]	364	573

It may be seen from the foregoing that although there was considerable effect even from the coarsest siftings, which passed through a sieve with 10 spaces or meshes to the linear inch and not through one with 20 meshes, the effect increased with the fineness of the siftings until the calcium carbonate in the finest particles from the ground limestone produced about the same effect as the same amount of slaked lime. The unsifted ground limestone was more

*Extension News Service, Vol. 1, No. 6, R. I. Experiment Station.
*1912-13 Report of the Pennsylvania State College.

slowly available than the slaked lime because, as may be seen by the yields, all except the finest particles had less effect in neutralizing the soil acidity.

At the Pennsylvania Station experiments conducted in wire baskets coated with paraffine in which two soils A and B were used, soil A serves best to illustrate the effect of different size ground stone on the growing crop.

The general plan of the experiment, with corresponding pot numbers was as follows. Erroneous conclusions were guarded against by using three baskets with each treatment.

	Pot Numbers, Soil A.
100-mesh limestone	1- 3
80-mesh limestone	4- 6
60-mesh limestone	7- 9
40-mesh limestone	28-31
20-mesh limestone	13-15
Not treated with limestone	a- c

The test plant adopted was red clover, this selection being due chiefly to the importance of the crop in the Eastern States and to its rather high degree of sensitiveness to soil acidity.

At the end of the experiment, the clover tops were harvested, weighed green, air dried and again weighed. The roots were carefully washed from the well-soaked soil, dried and weighed. The work presented the following conclusions:

1. The variations of yield of dry tops by individual pots are quite considerable in the case of the treatment with limestones of the three highest grades of fineness, but are not such as to obscure the general tendencies toward increase in crop with increase in fineness. The relative proportions shown by the averages must, however, be regarded as merely approximate.

2. On this highly acid, well-fertilized soil no clover lived long without lime.

3. The use of coarse 20-mesh limestone made some clover growth possible, but its beneficial influence was insufficient to produce a paying crop.

4. The yield following the use of 40-mesh limestone was about 5½ times that with the 20-mesh stone.

5. The gain from the use of stone finer than 40 mesh was large; the 60 mesh showing one-third more than the 40 mesh; the 80 mesh, one-eighth more than the 60 mesh. It is improbable that the cost

of grinding finer than 60 meshes to the inch is expended with much profit so far as this particular soil and productive condition are concerned.

6. The yield of dry roots increased in like direction with the tops, but not at the same rate. The top to root ratios, the roots from the 100-mesh treatment being here taken as 100, were: 20 mesh, 40; 40 mesh, 80; 60 mesh, 84; 80 mesh, 92; 100 mesh, 84. In other words, the tops weighed nearly as much as the roots except where the 20-mesh stone was applied.

Summary.

Ground limestone and oyster shells of different degrees of fineness vary in their degree of solubility in water and water charged with carbon dioxide according to the fineness of the material.

Different grades of fineness of limestone and oyster shells vary in their solubility in a soil solution according to their degree of fineness. In order to furnish as much soluble calcium, by the use of ground stone or ground shells to a soil as calcium oxide will furnish the stone or shells must be ground so that at least 90 per cent. will pass an 80-mesh sieve.

In the use of ground limestone, results have shown that this material when ground to pass an 80-mesh sieve, gives yields equal to and sometimes greater than calcium oxide.

Conclusion.

Better results will be obtained by using calcium oxide (lime) or limestone and oyster shells ground to pass an 80-mesh sieve than by using a coarser grade of limestone or shells. However marked increases will be noted by the use of large quantities of coarse material due in a large measure to the fine material that is found in any limestone after it has been ground.

THE MARYLAND AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 194. FEBRUARY, 1916.

SUDAN GRASS.

By Nickolas Schmitz.

Introduction.

In 1909 the United States Department of Agriculture* obtained from Mr. R. Hewison, Director of Agriculture and Lands, of the Sudan Government, a small quantity of seed of a grass known to the natives as "Garawi." This seed was planted at a testing station in northwestern Texas, and from the beginning looked promising. Further tests in other sections of the United States, under the name of Sudan grass, showed the plant to be adapted to a fairly wide range of conditions.

The Maryland Agricultural Experiment Station has tested this grass at College Park (Prince George's County) for four years, and in other sections of the State for three years. Practically everywhere, outside the mountainous sections, it has proven itself worthy of serious consideration as a forage crop on every farm in years when the regular hay crop is short, as well as on those farms where clover and timothy cannot be grown successfully. In the mountainous sections of the State its success is doubtful because of the cool climate.

Description.

In appearance and habit of growth Sudan grass resembles both Johnson grass and the cultivated Sorghums. It no doubt, however, is more closely related to the cultivated sorghums than to Johnson grass, being entirely free from underground root-stocks which makes Johnson grass a perennial and often a noxious and persistent weed (Fig. I).

*Farmers' Bulletin No. 605.

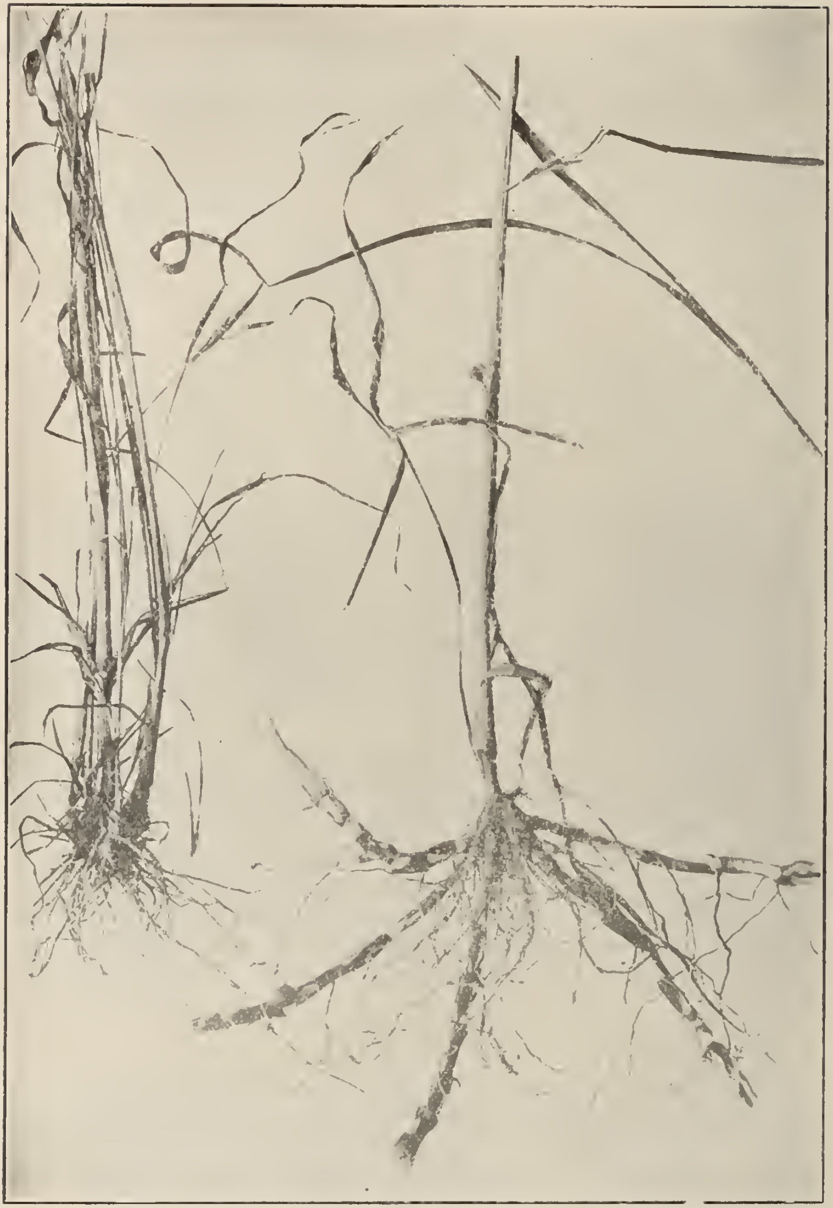

FIG. 1.—Root systems of Sudan grass and Johnson grass. Sudan grass on the left. Johnson grass on right, with well-developed rootstocks. (Farmers' Bulletin 605, U. S. Department Agriculture.)

Sudan grass, like the sorghums, is killed by the first frost in the fall, and since it does not persist in the soil by volunteer seeding, as is the case with many of our annual weeds, such as foxtail and crab-grass, it can never become a noxious weed.

When broadcasted, Sudan grass will grow to a height of 5 to 7 feet, with stems the size of a lead pencil or smaller. When grown in rows and cultivated it will grow to a height of 6 to 9 feet or more, with stems the size of a lead pencil and larger (Fig II).

Fig. 2.—Sudan grass near Eclo, Baltimore County, Md.

One of its most pronounced characters is profuse stooling; 50 to 100 or more stems maturing from a single seed is not uncommon when given plenty of room on fertile soil. Ordinarily about 5 to 8 will develop from a single seed.

Its Place on Maryland Farms.

Owing to its quick growth and heavy yields of hay, Sudan grass is very exhausting on the fertility of the soil. Therefore, it should never replace alfalfa, clover, cowpeas or soybeans, and it is even questionable if it should replace timothy on farms where timothy can be grown successfully. Aside from their greater feeding value, alfalfa, clover, cowpeas and soybeans are soil improvers, and any deficiency in yield as compared with Sudan grass will be more than compensated for by the increased yields of the succeeding crops.

Where, then, has Sudan grass a place on the average Maryland farm which normally produces clover, timothy and alfalfa, or other leguminous crops in sufficient quantities to meet the demands for hay?

Its greatest value will be found in its use as a catch hay crop—something to help out when there is a shortage of other hays. For this purpose it has no equal. Sixty to 70 days of good, warm, growing weather will insure at least one good crop in a season. One hundred and ten to 120 days will insure two crops. It follows, then, that in seasons when the regular hay crop is short, a clover, timothy or even a wheat or oats field may, after the crop has been harvested, be plowed and seeded to Sudan grass with the assurance of sufficient growing weather to mature at least one crop of hay.

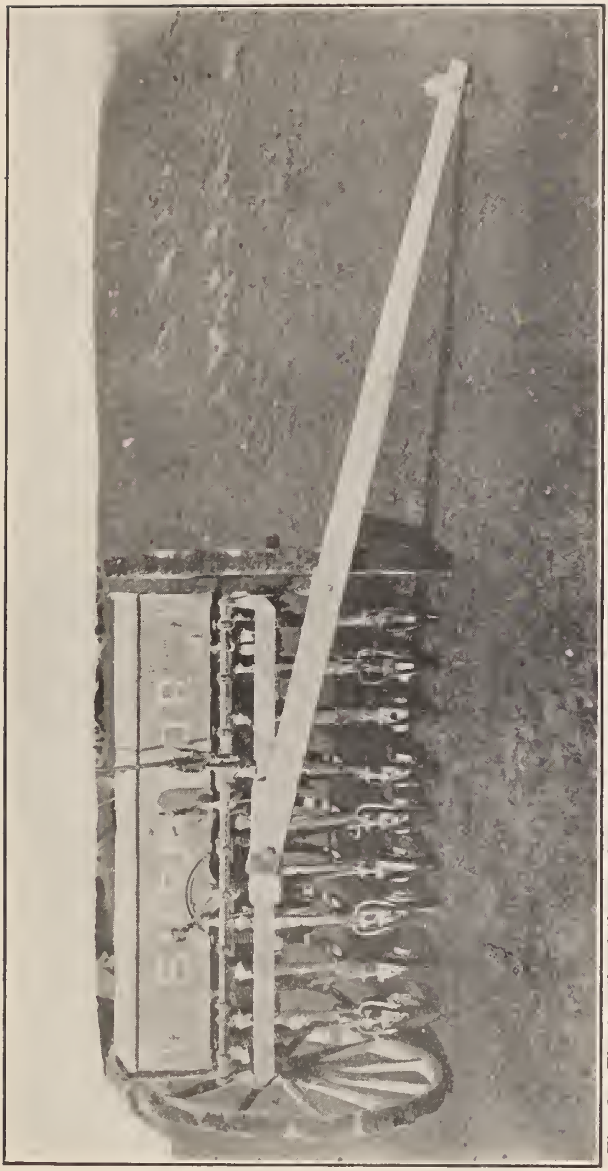

Fig. 3.—The length of the marker arms is 8 feet, 3 inches from the bolt fastening it to the drill to the bolt in the shovel. This will space the rows 28 inches apart when the seed is run through the middle and two outside discs, and 42 inches apart when the seed is run through the second disc from each side. The marker is held in place by a short chain from the frame hooked into a ring in the marker arm. The marker can be used on either side of the drill the same as the marker on a corn planter.

In sections of the Eastern Shore and in Southern Maryland where, owing to the lack of lime or other causes, clover and alfalfa are not grown successfully and cowpeas or soybeans cannot be grown in quantities sufficient to supply the demand for hay, Sudan grass should have a regular place in the rotation. Under such conditions it is certainly more economical and better farm practice to grow Sudan grass for forage than to buy hay.

Kind of Soil Required.

Tests made in different sections of the State show quite conclusively that Sudan grass is not at all exacting in its soil requirements; on the whole, however, slightly the best results have been obtained on fertile Sassafras loams; excellent yields have also been secured on both light-sandy and stiff-clay soils.

In fact, any soil which will grow a fair crop of corn will grow a crop of Sudan grass equally as well. The only important soil factor that must be taken into consideration is drainage. This must be good. It is as important for Sudan grass as for alfalfa.

Preparation of the Seedbed.

Thorough preparation of the seedbed is important. The manner of preparing and the final condition of the seedbed before planting is the same in every respect as that for corn or wheat.

Date of Seeding.

At the Experiment Station in 1913, seedings were made every few weeks from April 25 to July 31. The results obtained show clearly that nothing is gained in yield by seeding before the first of June. In fact, the April and May seedings showed a decided loss over the June seedings. This was due to the slow growth the first few weeks, which greatly aided weeds to get the start.

Table I.

Influence of Date of Seeding on Yield of Sudan Grass.

Date of Seeding	Rate of Seeding (Pounds)	Yield in Tons Per Acre	
		Very Fertile Soil	Medium Fertile Soil
April 25	25	2.16	2.17
May 9	25	3.35	2.02
May 31	25	4.10	2.54
June 13	25	4.40	3.30
July 18	25	2.03	1.87
July 31	25	1.13	.96

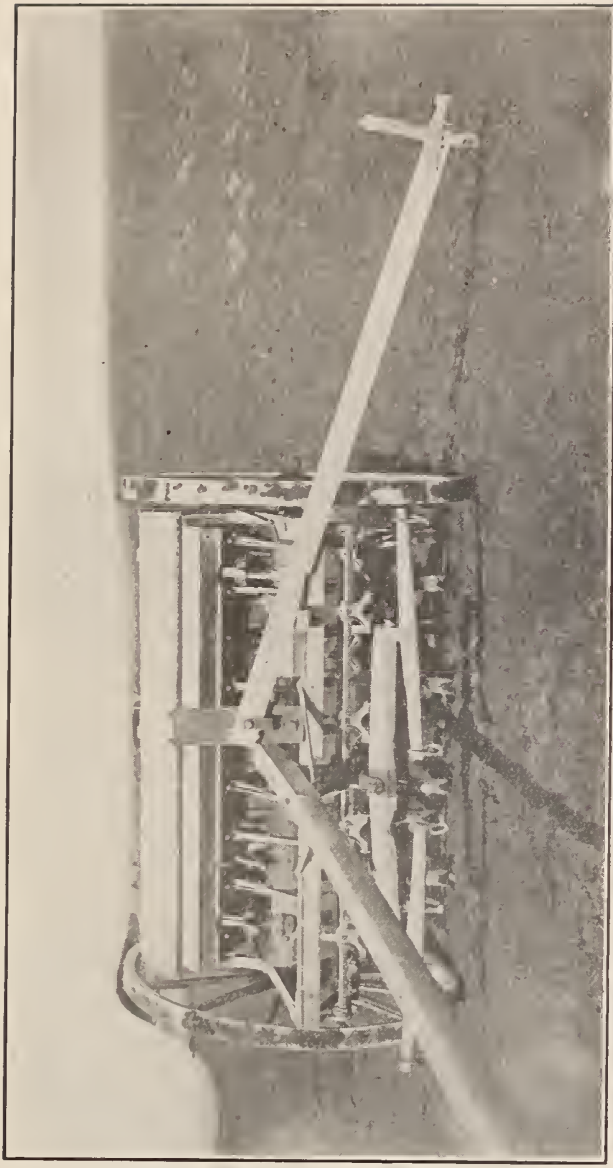

Fig. 4.—The length of the marker arm is 6 feet, 7 inches. By running the seed through the second hoe on one side of the drill and the third hoe on the opposite side the rows will be spaced 35 inches apart. The marker may be used on either side. It is held in place on one side by resting on a cross bar on top and against the front side of the frame. On the other side it rests on the tongue and against the frame. Since the marker arm remains stationary, the shovel must work on a hinge to allow for the necessary up and down play.

These results are in accord with the experience of farmers over the State the past two seasons and are what one would naturally expect, because Sudan grass is especially well adapted to a hot, dry climate. A cold, wet spell of weather after it is up will sometimes ruin the first crop. After the crop has reached a height of a foot or more, moderately wet weather does not hurt it providing the soil is well drained.

Everything considered, then, it is not safe to seed Sudan grass until the weather and soils have become thoroughly warmed. This, generally, is about the first of June. The most ideal time lies between the first of June and the first of July.

Rate of Seeding.

In our tests seedings at the rate of 15 pounds per acre have equaled in yield of hay seedings made at the rate of 30 pounds per acre. So much, however, depends upon the condition of the seedbed, the fertility of the soil, and the weather, that it is generally safer to sow 25 pounds or more per acre than less. If the soil is fertile and the seedbed has been well prepared, that is, finely pulverized, and is firm and moist, then 15 pounds per acre of good seed is sufficient. If, on the other hand, the soil is rather poor and the seedbed has not been well prepared, then at least 30 pounds per acre should be sown.

Table II.

Influence of Rate of Seeding on Yield of Hay.

Rate of Seeding	Tons Per Acre					
	1913	1914		1915		Average Three Years
	One Cutting	1st Cutting	2nd Cutting	1st Cutting	2nd Cutting	
15 pounds per acre	3.57	2.19	1.44	1.87	.87	3.31
20 pounds per acre	3.90	2.11	1.48	1.59	.90	3.32
30 pounds per acre	3.65	2.38	1.61	1.71	.83	3.41
40 pounds per acre	3.70	2.73	1.62	1.83	.97	3.62

When planting for seed in rows 24 to 30 inches apart, to allow for cultivation, 6 to 8 pounds of seed per acre should be used. When the rows are seeded 36 to 42 inches apart, 4 to 6 pounds of seed per acre is sufficient.

Method of Seeding for Hay.

For hay production Sudan grass should be sown broadcast, and the best implement for this purpose is the grain drill. Good, clean seed will feed through the drill when set for wheat at about the same rate wheat will; that is, if the drill is set to sow 2 pecks of wheat it will sow approximately 2 pecks of Sudan grass. If it is desired to sow 15 pounds of seed per acre, the drill should be set to sow 2 to 2½ pecks of wheat per acre, for 20 pounds, 3 to 3½ pecks, and for 30 pounds, 4 to 4½ pecks.

If the seed is not clean, considerable difficulty will be found, not only in getting it to feed evenly through the drill, but also in determining at what rate the drill should be set to sow the desired amount. Usually, this difficulty can be overcome by setting the drill for seeding oats and experimenting the first time across the field to determine at what rate the drill should be set to sow the right amount.

The seed may also be sown by hand, or with one of the numerous broadcasting machines on the market, and covered with a harrow. In this case, however, one-fourth to one-third more seed is required than when seeding with the drill, unless weather conditions are ideal for some time after seeding.

Depth of Seeding.

The proper depth of seeding, everything considered, lies between three-fourth inch and 2 inches, depending upon the character of the soil. On stiff clays, which bake quite readily after a heavy rain, it should not be seeded over three-fourths inch to 1 inch deep. On lighter soils, not subject to hard packing after a heavy rain, it may be seeded 1 to 2 inches deep. On very light, sandy soils 3 inches is not too deep.

Planting for Seed.

For seed production slightly the best results have been obtained when planting in rows and cultivating the same as corn. The closer the rows can be planted together and still allow room for cultivation, the higher will be the yield of seed.

The seeding may be done with the grain drill by stopping up the proper number of holes so that the rows will be the desired distance apart. The drill should be set to sow 5 pecks of wheat per acre. With a 9-hoe drill, 3 rows at a time can be planted, 28 inches apart, by running the seed through the two outside and the middle hoes. There will be, however, considerable difficulty experienced in spacing

properly the last planted row when going across the field in one direction and with the first row on the return trip, because the wheel next to the planted side of the field cannot be guided over the last drill row as when seeding wheat. This difficulty may be overcome by fastening a marker on the drill as illustrated in Fig. III.

Another method is to run the seed through the third hoe from each end, and then, when driving back, guiding the inside wheel over the mark made by the second hoe from the end. The objection to this method is that only two rows at a time can be planted.

Still another method is to run the seed through the third hoe on one side and the second hoe on the other side. This will plant only two rows at a time, 35 inches apart, and in this case a marker must be used, as illustrated (Fig. IV), to space the row accurately.

When to Cut for Hay.

When two cuttings are desired the first crop should be cut as it starts to head, which, if planted on or before the first of June, may be any time from the middle of July to the first of August, depending upon the weather. The second crop is usually ready for cutting 6 to 8 weeks after the first. It is probable, though, that the best hay will be secured if the crop is allowed to stand until after full-bloom. Therefore, when only one cutting can be secured, and in case time and weather will permit it for the last cutting, an advantage in both yield and feeding value will be gained by allowing the crop to stand until after full-bloom.

Fig. 5.—First cutting of hay, August 4th, 1915, from seed sown June 3rd.

Should the weather be unfit for hay-making after the crop has reached the proper stage of maturity, no material deterioration will result by letting it stand a week or ten days longer. This is due to the fact that Sudan grass holds its leaves well, which probably, like the leaves of sorghum, improve in feeding value up to the time the seed has reached the dough stage.

Fig. 6.—Second cutting of hay, 60 days after first cutting, in same field as shown in Fig. 5.

Method of Cutting for Hay.

The most common method of harvesting Sudan grass for hay is to cut with the mower and then use the same implements for curing and raking as those employed in harvesting a crop of clover or timothy hay. As stated before, it retains its leaves well and therefore may be tedded as often as desired during the curing process.

Sudan grass requires much more time for curing than timothy, but much less time than cowpeas. In this respect it compares very favorably with heavy crops of clover and alfalfa. At this Station the best hay has been secured when placed in cocks two or three days before hauling to the barn. During July and August, with fair curing weather, a heavy crop mowed on Monday will be ready for the tedder on Tuesday, for another tedding on Wednesday, for raking and cocking on Thursday, and for hauling in to the barn on Friday or Saturday.

Another method of cutting it for hay is to use the grain binder and tie in small sheaves. The sheaves should be set up in small shocks, the same as oats or buckwheat, and allowed to remain in the field until cured. When the weather for curing is good, this method of harvesting is preferable to cutting with the mower. In case of a wet spell at haying time, the hay can be saved much better if cut with a mower and handled in the usual way.

Cutting for Seed.

Owing to the large number of stools springing up from the base of every stalk and maturing at intervals, later than the main stem, there can be found in a seed crop heads which are in the blossoming, milk, dough and mature stage at the same time. This makes it quite difficult to determine at what time the maximum amount of seed will be obtained. Ordinarily the best plan is to wait until after the first heads are over-ripe; at this stage the largest number of ripe heads will be secured.

The best method of harvesting the seed crop is with the grain binder. The sheaves should be set up in fair sized shocks, tied at the top, and allowed to remain in the field until thoroughly cured. If the growth is exceptionally rank the corn binder will do far more satisfactory work than the grain binder.

Threshing.

When thoroughly dry, Sudan grass may be threshed with the ordinary grain thresher. The speed of the machine and adjustments of the concaves should be the same as for wheat. Usually, the air blast must be reduced and slight changes made in the adjustments of the sieves. It may also be threshed with the clover huller.

Yield of Seed.

The best yields of seed of Sudan grass are secured in sections of the West having warm, dry seasons. In those sections a yield of 1,000 to 1,500 pounds or more of seed per acre is not uncommon. In our tests the yield per acre has not gone beyond 400 pounds, the average being less than 300 pounds. On the other hand, several farmers have reported yields running from 600 to 800 pounds per acre.

The weight per bushel of good, clean seed in Maryland runs close to 35 pounds. Good, clean Western seed will weigh 40 pounds per bushel.

Legume Mixtures.

Tests at this Station have shown Sudan grass to be well suited to growing in combination with soybeans for hay. As will be noted in Table No. III, in no case was the yield of hay affected very much one way or the other, but the feeding value of the first crop was greatly increased, from 15 to 30 per cent. of the total weight of hay being soybeans.

Table III.

Yield of Hay When Soybeans and Sudan Grass Were Sown Together.

Rate of Seeding	Tons Per Acre				
	1913	1914		1915	
	One Cutting	1st Cutting	2nd Cutting	1st Cutting	2nd Cutting
15 lbs. Sudan Grass—¾ Bu. Soybeans	3.37	2.80	1.24	....	....
15 " " " 1 " "	3.25	2.81	1.76	....	....
20 " " " 1 " "	3.40	2.90	1.44	....	....
15 " " " 1½ " "	....	2.34	2.17	1.55	1.55
15 " " " 2 " "	....	2.03	1.74	1.59	1.65
20 " " " 2 " "	....	2.07	1.65	1.49	1.57

Our tests in growing Sudan grass in combination with cowpeas have been unfavorable. The cowpeas were not able to compete with the Sudan grass, while the soybeans more than held their own the first few weeks, the Sudan grass taking the lead later on. The poor showing of the cowpeas is not in accord with results of other investigators, and was due no doubt to the soil on which the tests were made. The soil was a mediumly heavy clay, well suited to soybeans, but not to cowpeas. Had the soil been light and sandy the reverse would probably have been true. At any rate, the nature of the plant would seem to make it far better adapted to growing with cowpeas than are either sorghum or millet. Its stems grow erect and are stiff enough to support cowpea vines, but not too coarse, as is the case with sorghum, or too fine, as is the case with millet. It cures much faster than sorghum and matures near enough with most varieties of cowpeas to make good hay.

The best results were secured when Sudan grass was seeded at the rate of 15 pounds per acre and soybeans at the normal rate of seeding, 6 pecks per acre. This same proportion will hold true when seeding with cowpeas.

For Soiling.

Preliminary tests indicate that Sudan grass is admirably suited to soiling purposes. It can be cut 3 to 4 times during its growing season, recovering quickly after each cutting, and yielding large quantities of palatable green food. It makes its most rapid growth during the hot, dry weather in July and August, when pasture is usually short.

Fig. 7.—Mixture of Sudan grass and soybeans. Soybeans seeded at the rate of 2 bushels per acre and Sudan grass at the rate of 15 pounds per acre.

For Pasture.

No pasture tests have been made, but a few farmers have reported very favorably on its use for both cattle and hog pasture. Being an annual, it can never take the place of the pasture grasses, and its value for pasture will be found in supplementing permanent pastures during dry, hot spells in midsummer and early fall. It should be remembered, however, that being a sorghum it is possible for Sudan grass to be a carrier of prussic acid, often present in fatal quantities in second-growth sorghums. So far, however, nothing has been reported which would in the slightest degree indicate the presence of prussic acid in Sudan grass at any time.

Pasturing should never commence until the grass is knee-high, because the young plants are easily pulled up. A good plan is to first cut one crop of hay and then pasture.

Feeding Value.

The results at this Station and the experience of farmers in this and other States prove beyond doubt that both the green forage and cured hay of Sudan grass are very palatable and readily eaten by all

classes of live stock. But so far not enough feeding experiments have been conducted to justify any definite conclusions being drawn as to its feeding value. Judging, however, from the chemical composition and digestible nutrients contained, it is evident that Sudan grass must be compared in feeding value with such crops as timothy, corn fodder, millet and sorghum.

The chemical analyses and digestion tests here reported were made by Herbert J. White,* Assistant Chemist of the Experiment Station.

TABLE IV.

COMPOSITION OF SUDAN GRASS.

	Water %	Ash %	Protein %	Ether Extract %	Crude Fiber %	Nitrogen Free Extract %
Sudan Grass Seed (cleaned)	10.82	6.41	13.54	4.51	1.19	63.53
Sudan Grass Straw	9.68	4.38	5.63	1.56	37.57	41.18
Sudan Grass Hay	9.88	4.27	5.92	1.69	31.39	46.85

TABLE V.

COMPARING THE CHEMICAL COMPOSITION OF SUDAN GRASS, CORN FODDER, MILLET, SORGHUM AND TIMOTHY.

	Water %	Ash %	Crude Protein %	Carbohydrates		Fat %
				Fiber %	Nitrogen Free Extract %	
†Millet	14.3	6.3	8.3	24.0	44.3	2.8
†Sorghum	9.7	7.8	7.4	26.1	45.9	3.1
†Corn Fodder	18.3	5.0	6.7	22.0	45.8	2.2
†Timothy	11.6	4.9	6.2	29.9	45.0	2.5
Sudan Grass	9.9	4.3	5.9	31.4	46.9	1.7

It will be noted that in chemical composition Sudan grass is a little lower than timothy in protein and fat, but a little higher in carbohydrates. Vinall,‡ on the other hand, has reported the average of 14 analyses for Sudan grass which runs a little higher than timothy in protein.

In the digestion tests a 2-year old bull was fed for a 9-day preliminary period, after which he was put on a 5-day test period. The hay fed in the test, and from which the chemical analyses were

*Now an Assistant Chemist at the Maryland Agricultural College

†Henry's "Feeds and Feeding."

‡H. N. Vinall, U. S. Department of Agriculture, in address before the Maryland Crop Improvement Association, 1915.

made, was only fair in quality, having been slightly rained on during the curing. The crop when cut for hay had reached the milk and early dough stage.

TABLE VI.

COMPARING THE DIGESTIBILITY OF SUDAN GRASS, CORN FODDER, MILLET, SORGHUM AND TIMOTHY.

	Dry Matter %	Crude Protein %	Carbohydrates		Fat %
			Fiber %	Nitrogen Free Extract %	
*Millet	65.0	60.0	68.0	67.0	64.0
*Sorghum	58.0	38.0	61.0	63.0	65.0
*Corn Fodder	66.0	45.0	63.0	73.0	70.0
*Timothy	55.0	48.0	50.0	62.0	50.0
Sudan Grass	60.6	35.4	67.1	63.3	41.2

It will be noted in Table VI that in percentage of digestible dry matter, the Sudan grass in the test ran a little higher than the average for timothy, but in percentage of digestible protein and fat, it ran lower, while for carbohydrates, the percentage was considerably higher than for timothy.

Of course, it is not safe to draw definite conclusions from a single test, but judging from the data at hand it is evident that further tests will not show Sudan grass to vary greatly from the feeding value of the crops with which it is compared in Table VI. It is also probable that when everything is taken into consideration it will compare more closely with timothy than any other hay crop grown in Maryland.

*Henry's "Feeds and Feeding."

THE MARYLAND AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 195 MARCH, 1916

ONIONS.

EXPERIMENTS AND CULTURE.

By Thomas H. White.

Introduction.

Experiments with onions have been in progress at this station for several years. Recently there have been many inquiries regarding onion culture, and while these experiments cover only a small part of the subject, the results obtained may be of use to those interested in growing this crop.

Character of Experiments.

1. Comparison of varieties.
2. Sowing seed in the open ground compared with sowing it in the hot-bed and transplanting the young plants.
3. Difference in yield between onion sets, seed sown outside, and seed sown in the hot-bed.
4. The effect of supplementing poultry manure with potash and phosphoric acid.
5. The effects of varying the amount of potash in the fertilizer.
6. The effect of wide and close planting on the yield.

Comparison of Varieties.

Two experiments were conducted to compare varieties; one during the summer of 1904, and, the other, the summer of 1915.

The soil used was of moderate fertility, being similar in this respect to much of the farm land in the State. The land upon which the onions were grown in the season of 1904 had been in sweet potatoes the previous year. Manure at the rate of about eight tons per acre had been applied in the rows for the sweet potatoes. After plowing and harrowing, which was done in early spring, a commercial fertilizer mixture was applied at the rate of 750 pounds per acre. The formula for the fertilizer used was:

Dissolved Phosphate Rock..................400 lbs.
Nitrate of Soda...........................400 lbs.
Muriate of Potash.........................200 lbs.

The analysis of this would be about 8 per cent. nitrogen, 8 per cent. phosphoric acid, and 12 per cent. potash, or as commonly expressed, 8-8-12.

Six varieties were tested. They were planted under two different conditions. One lot of the seeds was sown in the hot-bed March 4, and the other lot directly in the field on March 24.

The rows were made eighteen inches apart.

On May 3, the plants growing in the hot-bed were set outside.

The cultivation was done mainly by hand. A small horse cultivator was occasionally used to work up the soil between the rows.

The crop was harvested August 15.

TABLE 1.

Shows the yield in bushels per acre of varieties grown in 1904, and also the average weight of each bulb in ounces.

	SEED SOWN OUTSIDE		TRANSPLANTED FROM HOT-BED	
VARIETIES	Average Wt. of Single Bulb Ozs.	Bushels per Acre	Average Wt. of Single Bulb Ozs.	Bushels per Acre
Gigantic Gibraltar	1.3	198.7	4.2	453.1
Prizetaker	1.1	198.7	3.1	357.0
White Victoria	1.1	186.7	3.6	419.1
Yellow Strasburg	.5	56.2	2.6	292.8
Australian Yellow Globe	.5	89.6	2.5	285.2
Mammoth White Garganus	1.0	140.0	2.2	242.0

Season of 1915. The soil used this season was of moderate fertility and the last crop grown on it was Lima beans.

Rotted manure at the rate of ten tons per acre had been applied and plowed down for the Lima beans. The land was plowed in the fall of 1914 and was left unharrowed until early spring. After harrowing and smoothing, a small plow was used to make furrows twenty-four inches apart. A fertilizer mixture composed of:

Dissolved Phosphate Rock.................. 800 lbs.
Tankage ....1,000 lbs.
Nitrate of Soda........................... 200 lbs.

was applied in the furrows at the rate of 800 lbs. per acre.

This fertilizer would analyze about 5 per cent. nitrogen and 9 per cent. phosphoric acid, or 5-9-0.

After the fertilizer was distributed, a ridge was thrown up over it with the plow. A board was used to smoothe and flatten the ridge. The seed was sown on the flattened ridge with a small seed drill.

Seven varieties were used this season, and the seeds for the hot-bed plants were sown on March 6. The outside lot was sown March 24. The hot-bed plants were transplanted to the field on May 12. This was much later than planned, but the weather had been unfavorable for transplanting until that date.

The crop from the seed sown outside was mature and harvested on August 18, while that from the hot-bed plants did not mature until September 10.

TABLE 2.

Shows the yield in bushels per acre of varieties grown in 1915.

VARIETIES	SEED SOWN OUTSIDE Bushels per Acre	TRANSPLANTED FROM HOT-BED Bushels per Acre
Gigantic Gibraltar	239.3	239.2
Prizetaker	283.9	206.1
Yellow Globe Danvers	156.1	139.2
Yellow Dutch Strasburg	271.6	132.3
Southport White Globe	271.0	260.7
Large White Globe	283.0	207.3
White Portugal	223.2	139.4

SOWING SEED IN THE OPEN GROUND COMPARED WITH SOWING IN HOT-BED AND TRANSPLANTING YOUNG PLANTS.

This experiment was made in connection with the variety test so the preparation of the ground was the same in both cases.

The difference in yield between the individual varieties under the two conditions can be found in Tables 1 and 2.

For the purpose of comparison, Table 3 has been prepared from the average yields for the two seasons, grown outside and in the hot-bed.

TABLE 3.

Shows the difference in yield, in bushels per acre, between seed of all varieties sown outside and in the hot-bed in 1904 and 1915.

SEASON	SEED SOWN OUTSIDE	TRANSPLANTED FROM HOT-BED
1904	144.9	341 5
1915	261.1	189.1
Average	203.0	265.3

DIFFERENCE IN YIELD BETWEEN ONION SETS AND SEED.

These experiments were conducted during 1904, 1905 and 1915 to find the difference in yield between onions grown from seed and onion sets (For description of onion sets, see page 73). Yellow sets purchased from a seed dealer were used.

Fig. 1 shows onion varieties all grown under same conditions. (1) Gigantic Gibraltar; (2) Prizetaker; (3) Yellow Globe Danvers; (4) Round Yellow Danvers; (5) Southport Yellow Globe; (6) Australian Brown; (7) Yellow Dutch or Strasburg; (8) Mammoth Silver Skin; (9) White Silver Skin.

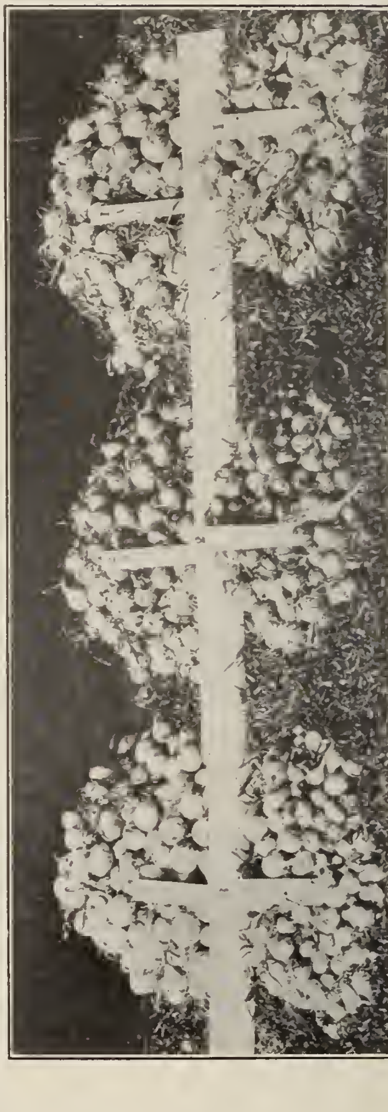

Fig. 2 shows three varieties of onions. Back row, grown from plants transplanted from hot-bed. Front row, grown from seed sown in field. (1) Gigantic Gibraltar; (2) Prizetaker; (3) White Victoria.

The work of 1904 and 1915 was conducted along with the variety tests, so the soil and preparation were the same as for those tests. For the season 1905, soil very similar to that of 1904 was used. It was manured during winter and plowed in the spring. After harrowing, fertilizer the same as for Experiment 1 was applied.

Seeds of two varieties, Gigantic Gibraltar and Prizetaker, were sown in hot-bed March 5.

The spring was cold and rainy and no outside seeding could be done until April 4. On that date, seeds were sown and sets were planted outside. The weather was so unfavorable that the seeds sown outside came up very poorly. For this reason, no record of yields could be kept.

The plants from the hot-bed were set on April 27 and they made a good growth.

TABLE 4.

Shows the difference in yield in bushels per acre between onion sets, seeds sown outside, and plants transplanted from hot-bed.

Type	Season 1904 Bushels per Acre	Season 1905 Bushels per Acre	Season 1915 Bushels per Acre	Average Bushels per Acre
Yellow Sets	207.4	333.7	155.0	232.0
Seed sown outside	198.7	.....	261.6	230.0
Plants from hot-bed	405.0	565.6	222.6	596.6

These figures show a decided difference in favor of the hot-bed grown plants. The sets averaged about the same as the seed sown outside. Onions grown from sets, however, matured three to four weeks earlier than those from seed. There is an advantage in this as they can be placed on the market before the crop from seed is ready.

THE EFFECT OF SUPPLEMENTING POULTRY MANURE WITH PHOSPHORIC ACID AND POTASH.

There is a popular idea that poultry manure is especially good for onions, and that it needs something mixed with it to produce good results. To test this, a plan to continue three years was outlined.

Based upon the amount of potash onions remove from the soil, it would appear that poultry manure is deficient in this element.

Dissolved phosphate rock is often recommended as being good to mix with poultry manure so this was added to one plot.

The experiments were conducted on a different piece of land each year. The plots were one-hundredth of an acre each. Plot 1 received 5,000 lbs. poultry manure and 98 lbs. of sulphate of potash per acre; Plot 2, 5,000 lbs. of poultry manure and 300 lbs. of kainit per acre; Plot 3, 5,000 lbs. of poultry manure; Plot 4, 5,000 lbs. of poultry manure, 400 lbs. of dissolved phosphate rock, and 98 lbs. of sulphate of potash per acre; Plot 5, no fertilizer applied.

After the ground was plowed and harrowed, shallow furrows thirty inches apart were made and the fertilizing materials were scattered in them. Afterwards the plow was used to form a ridge over the furrow. This was leveled with a board. Shallow drills were made, and yellow sets were planted as early in the spring as the weather would permit. The crop was harvested as soon as ready, usually about the middle of July.

TABLE 5.

Shows the yields of onions for three years, in bushels per acre, grown from sets and fertilized with poultry manure supplemented with phosphoric acid and potash.

PLOTS	LBS. PER ACRE	1909 Bushels Per Acre	1910 Bushels Per Acre	1911 Bushels Per Acre	Average 3 Years Bushels Per Acre
Plot 1	5000 lbs. Poultry Manure, 98 lbs Sulphate Potash	117.8	87.0	77 .7	94.1
Plot 2	5000 lbs. Poultry Manure, 300 lbs. Kainit	100.0	67.2	70.0	79.0
Plot 3	5000 lbs. Poultry Manure	107.1	78.5	68.5	84.7
Plot 4	5000 lbs. Poultry Manure, 400 lbs. Dissolved Phosphate Rock, 98 lbs. Sulphate Potash	80.3	78.5	62.8	73.8
Plot 5	Check—no fertilizer applied	71.4	64.0	38.8	58.0

Reference to Table 5 shows that Plot 1 yielded more each season than either of the other plots. This would indicate that sulphate of potash was helpful. Plot 3 was next best in yield, and this received no other fertilizer than the poultry manure. There was an average gain of ten bushels per acre by supplementing the poultry manure with 98 lbs. of sulphate of potash per acre, and a gain of twenty-six bushels per acre over the check plot when 5,000 lbs. of poultry manure was used alone. When 300 lbs. of kainit, on Plot 2, and 400 lbs. of dissolved rock, on Plot 4, were used, there was an average decrease of five and eleven bushels per acre, respectively. The yields were very low all through, which was probably partly due to the wide rows. If planted closer, double the crop could have been produced from the same land.

The Effect of Varying the Amount of Potash in the Fertilizer.

It is generally supposed that root crops need considerable amounts of potash. Most writers on the subject recommend a fertilizer with a high percentage of potash.

The plans for studying the effect of potash were to use the same amounts of nitrogen and phosphoric acid on each plot, but to increase the potash from two to eight per cent. This experiment was conducted in the season of 1914.

The materials used in making the fertilizer were dissolved phosphate rock, nitrate of soda, and muriate of potash, with some dry earth as a filler. These were apportioned so that the analysis would be approximately 4 per cent. nitrogen, 7 per cent. phosphoric acid, and 2 to 8 per cent. potash. Three lots were mixed. The first contained 2 per cent., the second 4 per cent., and the third 8 per cent. potash. Four plots were arranged for—Numbers 1, 2 and 3 receiving fertilizers, and Number 4 receiving no fertilizer. The plots each contained one-hundredth of an acre. The soil was a fairly fertile, rather stiff loam prepared as early in the spring as the ground could be worked. The fertilizers were applied broadcast at the rate of 1,000 pounds per acre after the land was harrowed. A small one-horse plow was used to make ridges, which were twenty inches apart. These ridges were rubbed and smoothed down, and the seed and sets were planted on them April 14. The season for a period of two weeks was wet, but after this it became very dry. The seeds came up poorly, especially on the fertilized plots. There was a much better stand on the check plot but not enough to be worth cultivating.

The sets grew fairly well and were harvested July 20.

Table 6.

Shows the yield in bushels per acre on the plots receiving different percentages of potash.

Plot No.	Nitrogen	Phosphoric Acid	Potash	Bushels per Acre
Plot 1	4%	7%	2%	118.4
Plot 2	4%	7%	4%	108.8
Plot 3	4%	7%	8%	87.0
Plot 4	...	...	...	117.0

Field notes on this experiment showing that the seeds came up better on the plot receiving no fertilizer, indicated that the fertilizer, under the prevailing conditions, was quite harmful. It was also noted that weeds of various kinds germinated and grew better on

the check plot, and only a few appeared on the fertilized plots until late in the season. It would appear from the yields that the extra amounts of potash were harmful, and also that the yield of Plot 1, which is the best of the fertilized plots, is only one bushel better than the check.

Effect of Yield of Wide and Close Planting.

This experiment was conducted in the season of 1908. Soil and fertilizer that seemed suitable were selected. Seed of the variety Prizetaker was sown in the hot-bed early in March. The rows were made thirty inches apart, for horse cultivation, and fourteen inches for hand cultivation. The plants were set in the field early in May. This season was very dry and the yield was not large.

The yields in bushels per acre were:

Rows 30 inches wide, for horse cultivation	85.7 bus.
Rows 14 inches wide, for hand cultivation	130.6 bus.

The heaviest yield is from the plot having rows fourteen inches apart and cultivated by hand. Evidently, the larger feeding surface for the roots in the wide rows was not sufficient to increase the size of the bulbs so that they would outweigh the greater quantity of the narrow rows.

Observations on Experiments.

Some useful facts noted while conducting the tests are mentioned below. Plants cannot be set quite as cheaply as Sets. They require more skillful handling.

A boy planted Onion Sets on one-hundredth part of an acre in one and a quarter hours. At five cents per hour, boys' wages, it would cost six dollars and twenty-five cents to set an acre with rows twenty-four inches apart.

When seeds are sown the seeding should be done just as early in spring as the condition of the weather and soil will permit. The same is also true of Sets and hot-bed plants. These, however, will make a partial crop, but seeds will fail to germinate, if sowing is delayed too long in the spring. Two seasons out of four, the seed sown outside failed to germinate well, but the stand was good the first and fourth seasons. For the latter two seasons, the seed was sown on March 24, but for the two seasons of failure, the seed was sown on April 4 and 14.

The crop when grown from sets matures earlier than when grown from seed.

Four to five thousand plants can be raised under one hot-bed sash of three by six feet.

Conclusions.

From the records and other observations made while conducting the experiments, the following conclusions are drawn:

The variety, Gigantic Gibraltar, grew the largest and made the best yield.

Prizetaker, White Victoria and White Globe all yielded well.

Hot-bed grown plants, on the average, produced more bushels per acre than either sets or seed sown outside.

Poultry manure (5,000 pounds per acre) made an increase of twenty-six bushels per acre over no fertilizer.

Poultry manure supplemented with 98 pounds of sulphate of potash per acre increased the yield to thirty-six bushels over the check.

A fertilizer containing 2 per cent. potash (obtained from Muriate) produced a better yield than a fertilizer containing either 4 per cent. or 8 per cent. potash.

Rows fourteen inches apart produced more onions than rows thirty inches apart.

Cultural Directions.

Outlook for Onion Culture in Maryland.

Maryland farmers have not gone extensively into onion raising. There is, as a rule, enough grown for the home markets during spring and summer, but the winter market is supplied from other States. The reason for this is probably on account of the uncertainty of raising them profitably from the seed. Onion Sets, however, never fail to produce a crop, and if planted to be on the market early, they will bring a good price. Those not sold at harvest time keep well for winter use or sales. The Eastern Shore and Southern counties of the State seem to be well located for onion growing from Sets. The northern and western counties ought to be equally as well adapted to raising onions from seed. Some very fine onions were grown from seed last year on the river lands between Allegany County and West Virginia.

The prices obtained for onions vary with the supply and demand. When plentiful, they have sold in some seasons as low as fifty or sixty cents a bushel. Again if the supply is short, they will bring a dollar and a half. It is best with this crop, as with other staple garden products, to plant them annually. This will tend to equalize the profits and will be found much more satisfactory than planting a crop only when high prices are anticipated.

Soil.

Onions will grow on a variety of soils, but, for various reasons, it is not wise to attempt their culture on the heavy clays. Muck soils when well drained and specially fertilized will produce a fine grade of onions.

Stony, rocky soils should be avoided as they would interfere very much with the crop cultivation, which is necessarily done largely by hand. The soil should be well drained and of such a composition that it would dry out early in the spring.

Preparation of Soil.

Thorough preparation of the soil is very important for onion culture. Plowing should always be done in the fall, especially if the land to be used is in sod, as it is important to get the vegetable matter all thoroughly decayed before sowing the seed. The depth of plowing depends a good deal upon the depth of good soil. The soil will get deeper as it becomes richer, and if a little of the subsoil shows on the bottom of the furrow slice each year, it will not be detrimental. Good land will eventually break up eight inches deep and be dark and moist when ordinary soils are light and dry. For the reason that the onion requires extra good conditions of soil and fertility, exhausting crops, such as corn and grains, should not be grown in the rotation. Crops that shade the land like clover or potatoes could be used and these would not impoverish the soil as much as grains. This rotation of hoed crops will also tend to reduce the weeds. Weeds are the bugbear of the onion grower, and, therefore, everything possible should be done to reduce the weed seeds in the soil. If the stable manure that is used is piled and fermented before applying, many of the weed seeds in it will be destroyed. Thorough harrowing in the spring with disc and spike tooth harrows, and at

the same time some sort of rubber or float to level the surface, is highly important especially if seed is to be sown.

Fertilizing.

Barnyard manures should be used to provide humus and also some fertility. This, however, can be supplemented with the commercial concentrated manures. Bone meal, dissolved phosphate rock, tankage, dried blood, nitrate of soda, muriate and sulphate of potash, Kainit, and wood ashes are all used. The experiences with fertilizers for onions are many and varied and a variety of combinations are recommended.

On the muck soils a high percentage of potash and phosphoric acid has been used to a good advantage. Ordinarily it pays to use a good grade of fertilizer. If some of the elements are in excess for the onions, they will be used later by the crop which follows. Always bear in mind that an excess of chemical fertilizers is injurious in a dry season. For this reason 750 to 1,000 lbs. of fertilizer analyzing 5 per cent. nitrogen, 8 to 9 per cent. phosphoric acid, and 3 to 4 per cent. of potash, is about as much as should be used. In fact, in many cases much less would do if used in connection with barnyard manure plowed down. The fertilizers should be well mixed with the soil. This is very important if seeds are used. If the weather conditions are such that the seeds can germinate quickly, an excessive amount of soluble fertilizer salts in the soil may do no harm, but if germination is delayed for any length of time much of the seed may be injured and a poor stand result.

Nitrate of soda may be used as a top-dressing after the plants are well up and growing freely. It is generally used mixed with bone-meal or phosphate rock. Two hundred pounds per acre is a helpful and economical dressing.

Methods of Propagation.

Onions are mainly grown from seed that is produced on a stalk which shoots up from the bulb the second season of its growth. To produce seeds, large, fine onions that were harvested in August are set into the field late in September or early in October. These bulbs will commence to grow at once and the following spring they will blossom and produce seed.

The next most important method of raising a crop is by using what are termed sets. These sets are produced by sowing the seed quite thickly in a clean, moderately fertile soil. The seed is sown

early in the spring and on account of thick seeding, the bulbs do not grow very large. They are harvested just as soon as the tops begin to die. After being allowed to dry in the field a few days, the tops are pulled off and the bulbs are placed in shallow boxes and stored away in a dry, frost-proof, but not heated building. They are not usually sold under a variety name, but as yellow or white onion sets. The Yellow Globe Danvers seed is largely planted for this crop, but any variety may be used. When these sets are again planted, they start growing at once and if placed a few inches apart they will develop into full-sized onions. It is sometimes necessary to use the largest sized sets for pickles, as they will shoot to seed very quickly after planting. Good, firm bulbs, about the size of a large cherry, make good sets.

There is also a class of onion called Multipliers. One variety of this class bears small bulblets in the seed stalks instead of seeds. These are saved and handled much the same way as the sets. Another variety of the multiplier type has a compound bulb in which there are several small bulbs compressed in one. The smaller of these, if planted, will increase in size until they become full-grown bulbs.

Of these different methods of propagation, the seed method is by far the most used. The sets, both those grown from seed and the multipliers, are more largely used in the South where the conditions are unfavorable for the germination of the seeds.

Time of Planting.

The time of planting for the main crop is just as early in the spring as the ground can be worked. When the green onions are needed in the early spring to be used or sold in bunches, they are planted in the fall. The very earliest that appear on the market, and which are called ''scallions,'' are produced by planting large mature bulbs several inches deep in light, rich soil early in September. These will commence to grow at once, and if a little earth is pulled up around the stems they will become white, very tender and sweet. Each onion planted will produce three or four stalks and if covered with soil deep enough they will have five to six inches of white portion, which is highly esteemed for boiling and for soups. These stalks must be promptly used, for as soon as the warm spring days approach each stem will produce a seed stalk.

The next lot to follow are grown from the small sets planted in September, and these will make round bulbs which are ready for use when quite small.

To follow this lot more sets are planted very early in the spring, and some of these can be used or sold bunched in the green state and

the remainder be left to mature for winter use. The next to follow will be those grown from the early sown seed.

Methods of Planting.

If the crop is to be worked with hand tools, the seed may be sown or the sets planted in rows twelve or fourteen inches apart. If the patch is larger than a few square rods, a small drill will be needed for sowing the seed. The rows should be made as straight as possible and some stakes or string should be used to get the first row correct. The guide marker on the seed drill will make a mark for all the rows afterwards.

If the crop is to be cultivated with a horse; then a small plow or disc marker is used to throw up a ridge. This ridge is flattened with a light drag or roller. The seed is then sown on the flattened ridge.

If plants are to be transplanted from the hot-bed, they can either be set alongside a line stretched tightly across the field, or in a mark made by a light marker. If sets are to be planted, a deeper mark is needed and they are pressed, base downward, firmly into the soft soil.

Market gardeners who plant the sets for selling in bunches in a green condition often plant the crop in beds. The beds are formed by leaving a two-foot space every six feet, which space is called an alley. If the land is rather flat so that water is likely to lay on it, the soil is shoveled from the alleys on to the beds. The alleys then serve to drain the slightly elevated beds. The rows are made across the beds, nine inches apart, extending from one alley to another. In weeding or gathering the crop these alleys are used as walks. If the weather is wet the soil around the plants is not puddled and packed.

The quantity of seed to be sown depends somewhat upon the purpose for which the crop is to be used. If sets for the next season's planting are to be grown, then as many as two hundred seeds are sown to a foot. If small onions suitable for pickles are wanted, half that amount will be sufficient. If the crop is to make large onions and the seed is known to be of strong germinating quality, twenty to twenty-five seeds to the foot will be an abundance.

Cultivating.

The crop must be kept entirely free from weeds. Just as soon as the seedlings get through the ground, the cultivation must be necessarily light on account of the small size of the plants. Small teeth like rake teeth will be found all that is needed for first cultivation. These can be found on all the standard wheel hoes. Such wheel hoes

are very useful for this crop and can be bought with large or small wheels. The large wheel type. usually runs easier on account of the greater leverage of the wheel. Later cultivation must all tend towards keeping weeds destroyed. There will probably be some necessity for hand weeding along with the cultivating. The cultivators should be kept going as late as possible, but care should be taken not to push the soil up against the plants. The bulbs will be firmer and keep better if they grow above the soil. Where horse cultivation is used, all hand hoeing that is done should be away from the plants and towards the middle of the rows. The plants setting on a slight ridge makes this hoeing very easy to do. When onions are set in beds, the weeds and some of the soil can be scraped into the alleys.

If sets have been planted a close watch must be kept for seed stalks. As soon as they appear they should be broken off close to the bottom, and this will allow the bulbs to develop. If the stalk is allowed to produce seed the bulb will become hollow and perish.

Thinning.

When the onions are sown in drills, if all large onions are desired, the young plants must be thinned as soon as they are large enough. If the crop is to be marketed where pickles and sets can be disposed of, no thinning need be done. The young plants which are transplanted from the hot-bed will not need thinning as they are placed the proper distance apart when planted. The same thing applies to

Fig. 3 shows Prizetaker onions unthinned. Good development when grown in wide rows for horse cultivation.

sets. The distance apart also depends somewhat on the variety. The large varieties should be placed three or four inches apart, but the smaller varieties need less.

Where horse cultivation is used the bulbs can be set closer together as the rows are wider apart and there is more moisture and plant food to draw upon. If the onions are so close as to touch one another, when nearly mature, no harm will be done because they will simply crowd each other to the side a little.

Varieties.

The greatest demand is for the yellow, or straw-colored, and the white varieties. There is scarcely any demand for the bright red onions, and, therefore, they need not be considered for commercial purposes.

Gigantic Gibraltar is a large, straw-colored, globe-shaped onion of very fine quality, and when well grown it could be sold to the same fancy trade as the large imported Spanish onion.

Prizetaker is another good variety, with a rather dark straw-colored skin.

White Globe and White Victoria have white skins and grow to a large size.

Another good variety is Maules Commercial, which grows quite large and is very similar to Gigantic Gibraltar.

Harvesting.

Onions should be taken out of the ground as soon as the tops have died down. There is nothing gained by leaving them in the soil after they are mature, and sometimes there is a very great loss. This loss may be due to rotting, or what is probably more common, sprouting. If the second growth gets started while onion is in the field, it will continue after harvesting and, of course, spoil the stock. For these reasons, if for no others, the crop should be pulled from the soil promptly and placed in the house as soon as possible. A day or two is generally sufficient to dry up the tops so that they may be pulled or cut from the bulb. If there is floor space enough, they may be spread three or four inches deep over the floor. If the crop is to be grown continually, however, it will be well to provide shallow boxes than can be placed in tiers on shelves or racks provided for them. The onions should be kept cool and dry. Slight freezing may not be injurious, but it is well to provide a frost-proof building for storage, as hard freezing will make them soft and undesirable.

Grading and Marketing.

Onions like all other garden products should go on the market carefully assorted, and in a package that is neat, suitable and economical. Sometimes it is necessary to put them up in the package that is most popular on the market to which they are sent. This may be sacks, barrels or crates. Local markets will usually take them in bushel boxes or baskets. A neat package goes a long way towards selling the product in it.

The grading should be carefully done, as better prices can be secured for them if properly assorted into large, medium or small sizes.

Fine specimens of the Gigantic Gibraltar variety will bring a fancy price on some markets when crated in flat, shallow crates so that each individual onion can be seen.

Diseases and Insects.

Onions in Maryland are not subject to many diseases. One of the worst troubles is a rot that seems to get started in the field and continues to develop after the onions are stored. Prompt removal of the crop from the field just as soon as they are ripe will help to prevent this rotting.

The most troublesome insects are the Thrips. These small pests infest the green tops by thousands, and in dry weather they do considerable damage. They eat off the outer skin, which gives the plant a whitish appearance and checks its growth. Spraying with Black Leaf 40 or kerosene emulsion will destroy them.

Publications on Onion Culture.

Those who wish to study the subject of onion culture further will find the following publications helpful:

Farmers' Bulletin 434—"The Home Production of Onion Seed and Sets."

Farmers' Bulletin 354—"Onion Culture." Both of the above named may be obtained from the United States Department of Agriculture, Washington, D. C. Bulletin 175, of the Agricultural Experiment Station, Urbana, Illinois, records a number of interesting experiments. This may be obtained upon request.

A book by T. Greiner, "The New Onion Culture," published by the Orange Judd Company, New York, treats the subject of growing plants in hot-beds quite exhaustively. Some seedsmen issue leaflets that may be obtained with seed orders. Nearly all seed catalogues give cultural direction and descriptions of varieties.

THE MARYLAND AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 196 APRIL, 1916

METHODS AND PROBLEMS IN PEAR AND APPLE BREEDING.

By W. R. Ballard.

Investigations in the improvement of orchard fruits have been in progress at the Maryland Experiment Station for eleven years. The work with pears was begun in the spring of 1905 by S. B. Shaw under the direction of W. N. Hutt. Upon the resignation of Shaw, the writer took up the work in 1906. The work with apples was started in 1907 by C. P. Close, who became head of the Horticultural Department in that year. Since 1912 the writer has had full charge of the breeding projects with both of these fruits. While a number of seedlings from the early crosses have fruited, the data of such results will be reserved for a later publication. The present bulletin is limited to a discussion of some of the methods which have been found useful and some of the problems which have been encountered in these investigations. It is hoped that the data and observations here presented may prove of interest and value to investigators in a similar field.

Knowledge of Varieties.

In the improvement of any fruit an intimate knowledge of varieties is essential to intelligent effort. Such information should include not only the adaptability of varieties to climatic conditions, habit of growth, season, productiveness, character and quality of fruit, but should also include as far as possible information concerning disease resistance and historical data in regard to parentage. The great majority of varieties grown in this country are undoubtedly of hybrid origin. This is due to the promiscuous cross-pollination carried on

by bees and other insects. This fact makes the value of a variety for breeding purposes somewhat problematical since many characters show up in the progeny which can not readily be detected in the parents. This hybrid nature, however, works to the advantage of the breeder of orchard fruits for wide variation occurs in the first generation, so that he does not have to wait until the second generation for such results, as would be the case were he working with pure strains. Investigations here and at other stations indicate that the greatest improvement is to be secured by using for breeding purposes only the best of the varieties now in existence. Only occasionly is it necessary to depart from this rule in order to utilize some particular character of an otherwise inferior variety.

The Blooming Period.

Since pollination can be done only during a comparatively short blooming period, it is essential to be thoroughly prepared for work when the time comes. There is more or less variation in the time of blossoming of different varieties, although in abnormal seasons all varieties have been known to bloom at about the same time. Advantage can often be taken of this variation by using the early bloomers as the male parent. This enables one to collect pollen in workable quantities before the buds of the later varieties are ready to be pollinated. Weather conditions are also more likely to be favorable for pollinating work at this later period. The blooming dates of a few of the common varieties of pears grown in Maryland are given in the accompanying table. Some of the Oriental hybrids, like Kieffer, have an early blooming season. For data on the blooming periods of apple varieties, see Bulletin 178 of this Station.

Table I. Blooming Records of Pears.

Variety	No. of years	Average date of first bloom	Average date of last bloom
Kieffer	5	April 8	April 16
Duchess	5	" 10	" 19
Mannings Elizabeth	5	" 10	" 20
Anjou	5	" 11	" 21
Lawrence	5	" 12	" 19
Howell	4	" 12	" 20
Seckel	5	" 13	" 20
Buffum	4	" 16	" 20

Collecting and Ripening Pollen.

Normally the anthers burst and the pollen is shed shortly after the blossom opens. This usually takes place early in the day. In cross-

pollination it was formerly customary to break off recently opened blossoms and brush the stigmas of the emasculated buds with the opening anthers. There was always danger in this method that bees or other insects had already visited the flowers leaving a deposit of foreign pollen in the blossom used for pollinating. Where the purpose was simply to get variation without regard to parentage, this method worked very well in a small way, but where a study is to be made of the laws of inheritance more accurate methods must be followed.

A simple method used by the author to insure a good supply of pollen is to gather a number of buds which are just ready to open but not far enough advanced to allow the entrance of insects. This would usually be about a day before they would normally open. By grasping the petals between thumb and forefinger, they can easily be rubbed off, together with the anthers. These are then collected on a newspaper and after the loose petals and other waste materials have been sifted out, the anthers are transferred to glass dishes (petrie dishes are excellent for this purpose) and placed in a moderately warm dry atmosphere. The anthers will soon burst open releasing the pollen grains. When the pollen becomes dry it is protected from moisture until needed. Handled in this way it may be kept for several days, although it is always advisable to use it as soon after being collected as convenient. Should doubt arise as to its viability, a test of its germinating power is made by placing a small quantity of pollen in a 2 per cent. solution of sugar and keeping it at a moderate temperature. If upon examination under a microscope after a few hours, the pollen grains are found to have germinated and sent out their pollen tubes, it is usually safe to use the remaining pollen for crossing. Each kind of pollen is carefully labelled in order that no uncertainty may arise as to its source.

FIG. 1. Method of emasculating apple buds, buds ready for pollination and anthers collected in petrie dish.

Emasculation.

In order to effect a cross the buds to be pollinated should first be emasculated, so that self-fertilization may not take place. The following method has been used by the writer for several years with pears and apples with excellent results. The bud is held firmly between the thumb and forefinger of the left hand. Emasculation is then accomplished expeditiously by inserting a well sharpened scalpel into the side of a bud just below the calyx. Then by giving it a quick upward jerk, the whole corolla is removed, carrying with it all the anthers. (See Figure 1.) Pear buds are especially easy to work in this manner, but in the apple the abundant pubescence soon dulls the scalpel necessitating frequent sharpening for the best results.

Fruit buds of the pear and apple are borne in clusters of six or more. Ordinarily only one or two of these buds set fruit and come to maturity. In hybridizing work the question arises as to the number of buds in the cluster which should be emasculated and pollinated. The central bud develops previously to the others so that it is safer to remove it. The best results have followed the working of the majority of the buds in the cluster, since the emasculation can be done in about the length of time it would take to remove the extra buds, and pollination requires very little longer time. Sometimes several clusters are close together and may be enclosed in a single bag. As many as eleven fruits of the Seckel pear have been secured under one sack in this way.

Pollination.

Until recently it has been customary to emasculate the buds, cover at once with a paper sack and leave for a day or so until the stigmatic surface reaches a receptive condition before pollination is done. The writer has found that equally good results are secured by pollinating at the time of emasculation, provided this operation is delayed until the buds are nearly ready to open. Pollen will remain on the stigma in good condition until it can germinate in the nectar which is secreted on the stigmatic surface. This eliminates the extra work of removing the sacks for pollination and replacing them. A camel's hair brush is frequently recommended for applying the pollen but the writer has found the tip of the finger to answer the purpose more satisfactorily.

Bagging and Labelling.

After pollination the buds are covered with manilla paper sacks and carefully labelled. Time is saved by giving the labels simply a

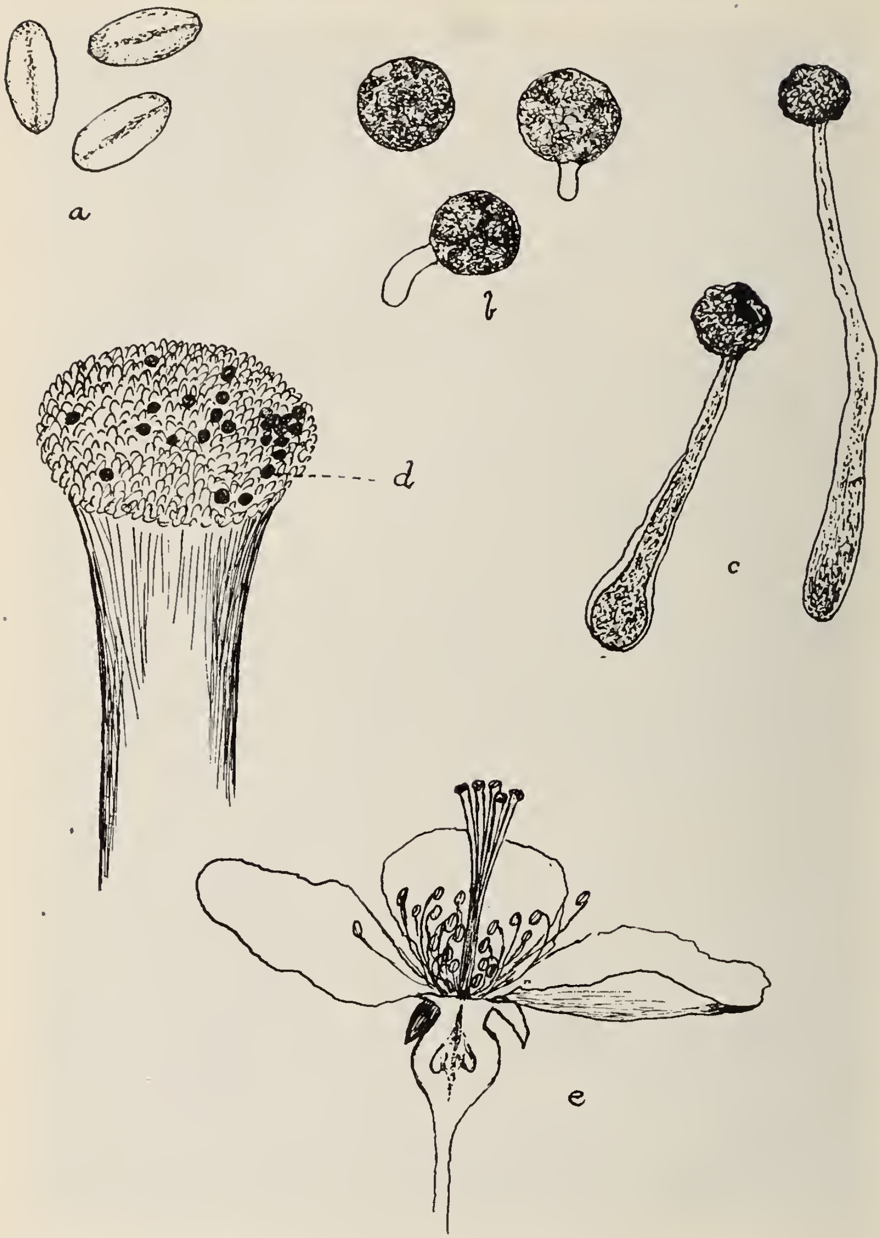

FIG. 2. Pollination in the Pear, (a) pollen grains in the dry state, (b) pollen grains in sugar solution beginning to germinate, (c) pollen grains showing the protoplasm collecting in the end of the pollen tube, (d) pollen grains on the stigmatic surface, (e) cross section of pear flower (all much enlarged).

serial number for identification. Other data of the cross is kept in a notebook. In recording the cross it is customary to write the name of the female parent first, followed by that of the male parent, e. g., Seckel x Kieffer.

Setting of the Fruit.

Not much is yet known about the sexual affinities of our cultivated varieties of pears and apples. Unfavorable seasonal conditions and some unknown factors, probably of a physiological nature, make this subject a confusing one. The writer has often noted trees loaded with fruit blossoms which set an extremely small amount of fruit, notwithstanding the fact that, what are generally considered favorable weather conditions for pollination prevailed. Such failures do not appear to be due to lack of pollen, for even where buds are thoroughly pollinated artificially, the percentage of fruit set seems to correspond with that of the tree as a whole. It is true that certain crosses generally give better results than do others. Pears generally set a higher percentage of fruit than apples whether pollinated naturally or artificially. A study of the table which follows may be found of interest in this connection. This contains in a condensed form the total number of fruit buds pollinated and the number and percentage of fruit set in the breeding work with pears and apples at this Station during a period of ten years. As will be seen, of the total number of pear buds pollinated, the percentage which set fruit was 24.2, while that of the total number of apple buds pollinated was 9.9. The variation in the different crosses is quite noticeable, some consistently failing to set fruit, while others set well. One of the most remarkable sets of fruit was recorded in the spring of 1910 when 651 fruits of the Seckel pear set, out of a total number of 807 buds pollinated with Kieffer pollen. This amounts to about 80.6 per cent. Over a series of years, however, the average drops to 37.8 per cent.

Table II. Summary of Pear and Apple Crosses.

Parentage	Number of buds pollinated	Number of fruit set	Per cent. of fruit set
Pears.			
Anjou x Bartlett	192	0	....
" x Duchess	128	0	....
" x Kieffer	222	52	23.4
Bartlett x Seckel	7	0	....
Belle Lucrative x Seckel	2	0	....
Buffum x Seckel	7	2	28.5
Chambers x Lawrence	4	0	....
" x Seckel	6	0	....
Duchess x Kieffer	817	100	12.2
" x Seckel	8	1	12.5
Easter Beurre x Seckel	1	0	....
Garber x Anjou	5	0	....
" x Seckel	2	0	....
Howell x Kieffer	3	0	....
" x Seckel	11	0	....
Kieffer x Anjou	310	66	21.2
" x Bartlett	15	0	....
" x Buffum	55	0	....
" x Duchess	896	207	23.1
" x Easter Beurre	15	0	....
" x Howell	75	0	....
" x Lawrence	4	0	....
" x Mannings	20	0	....
" x Seckel	785	187	23.8
King Karl x Bartlett	24	0	....
Lawrence x Anjou	96	0	....
" x Kieffer	37	2	5.4
" x Seckel	11	0	....
LeConte x Seckel	8	0	....
Mannings x Bartlett	172	0	....
" x Duchess	140	0	....
" x Kieffer	35	0	....
" x Seckel	14	0	....
Seckel x Anjou	178	90	50.5
" x Bartlett	60	0	....
" x Duchess	260	0	....
" x Kieffer	3,325	1,258	37.8
Total	7,772	1,875	24.2

Table II. Summary of Pear and Apple Crosses—Continued.

Parentage	Number of buds pollinated	Number of fruit set	Per cent. of fruit set
Apples.			
Bloomfield x Delicious	40	16	40.
" x Oldenburg	43	5	11.6
Delicious x Grimes	64	0	....
Early Harvest x Early Ripe	489	1	0.2
" " x Red June	799	4	0.5
" " x Williams	461	10	2.1
" " x Yellow Transparent	290	2	0.6
Early Ripe x Chenango	180	0	....
" " x Early Harvest	577	43	7.4
" " x Kinnard	42	0	....
" " x Red Astrachan	124	3	2.4
" " x Red June	601	26	4.3
" " x Stayman	285	8	2.8
" " x Williams	327	41	12.5
" " x Yellow Transparent	564	120	21.2
Gravenstein x Doucin	220	48	21.8
Grimes x Akin	35	4	11.4
" x Early Ripe	41	1	2.4
" x Stayman	878	41	4.6
Ingram x Rome	52	0	....
" x Stayman	242	0	....
Mother x Bonum	54	13	24.
" x Stayman	606	4	0.6
Nickajack x Stayman	371	0	....
Oliver x Akin	34	1	2.9
Paragon x Bloomfield	60	0	....
Red June x Early Harvest	451	93	20.6
" " x Early Ripe	775	50	6.4
" " x Grimes	35	0	....
" " x Williams	692	15	2.1
" " x Yellow Transparent	1,012	203	20.
Rome x Akin	47	0	....
" x Stayman	604	0	....
Stark x Red Astrachan	84	0	....
Stayman x Bonum	50	3	6.
" x Delicious	66	4	6.
" x Doucin	40	0	....
" x Early Ripe	129	3	2.3
" x Gravenstein	300	0	....
" x Grimes	1,456	22	1.5
" x Nickajack	2,043	269	13.1
" x Williams	280	40	14.2
" x Yellow Transparent	10	0	....
Williams x Early Ripe	244	43	17.9
" x Stayman	14	0	....
" x Yellow Transparent	180	24	13.3
Wolf River x Yellow Transparent	40	8	10.
Yellow Transparent x Early Ripe	975	262	26.8
" " x Nickajack	98	33	33.6
" " x Oliver	47	21	44.6
" " x Red Astrachan	106	36	33.9
" " x Red June	60	26	43.3
" " x Stark	35	0	....
" " x Stayman	212	0	....
" " x Williams	475	206	43.1
Total	17,653	1,751	9.9

After the June drop the paper sacks are removed and a record made of the number of fruit set. The fruit is then covered with bags made of mosquito netting which allows a good development of the fruit and prevents loss, should it mature and fall off before being picked. In cases where specimens have fallen out of the sacks accidentally, the scars which result from removing the calyx in emasculation often furnishes a convenient mark of identification. A few instances were noted where the development in the paper sacks was hindered by infestations of aphids. Protected from their natural enemies the aphids multiplied enormously until the sacks contained great masses of the insects.

Gathering and Planting the Seed.

As the fruit ripens it is gathered and the seed removed when fully matured. The number of seeds produced by different varieties varies considerably, a fact which may often be turned to advantage by choosing prolific varieties as female parents. A few records presented in Table III may serve to emphasize the importance of this factor. While the number of fruits taken into consideration in some cases is small, there is enough data to indicate the possibilities in this direction. Red June has usually run high in the number of seeds produced, in one instance eighteen seeds being obtained from a single fruit.

Table III. Number of Seeds Produced by Varieties in Different Crosses.

	Number of Fruits	Number of Seeds Secured	Average Number of Seeds per Fruit
Pears.			
Kieffer x Duchess	67	488	7.2
Kieffer x Seckel	124	776	6.2
Seckel x Kieffer	517	1,804	3.4
Apples.			
Early Ripe x Red June	20	147	7.3
Early Ripe x Yellow Transparent	104	460	4.5
Red June x Early Ripe	90	1,042	11.5
Red June x Yellow Transparent	171	1,596	9.3
Stayman x Nickajack	195	551	2.8
Yellow Transparent x Early Ripe	191	896	4.5

The seeds are kept in a dry place until time to plant. After trying various methods the writer has found that one of the most satisfactory ways of handling the seed is to plant them in thumb pots or

flats in light well-drained soil and place them in a cold frame early in the fall. There is always a certain percentage of loss of pots from freezing and bursting so that flats are more economical. To prevent getting the seed from the different crosses mixed, the greatest care must be exercised. No one, who has not worked with things of this sort, can appreciate how easy it is to get the labels or seeds misplaced.

Handling the Seedlings.

Early in March the seeds are removed to the greenhouse and are given gentle heat. Germination usually takes place rapidly under such conditions. It is essential to water with great care at this stage to avoid loss from damping-off fungi. Slugs seem to be extremely fond of the young seedlings and they should be guarded against. A trail of some such material as soot, lime or kainit surrounding the pots or boxes makes a good deterrent. Seedlings in flats are potted off after the first two or three true leaves appear and are then transplanted to the nursery row when danger of frost is over.

Early Elimination of Undesirable Types.

Since fruit trees are grown primarily for their fruit, it would be highly desirable from an economical standpoint to eliminate undesirable seedlings at an early age. After considerable correspondence with plant breeders, the writer reached the conclusion that, in the present state of our knowledge of the subject, no satisfactory basis of elimination has yet been worked out. In view of the importance of determining whether there are correlated characters which can be used for that purpose, it seems desirable to grow all seedlings up to the fruiting age in order that tree and fruit characters may be compared. The prevailing opinion seems to be that the best results are obtained from seedlings showing a close resemblance to the smooth appearance of our improved forms. In regard to this point, Mr. Joe A. Burton, who is in charge of the apple breeding work of the Indiana State Horticultural Society, states that he inquired of a prominent plant breeder if anything could be done in selection. Mr. Burton writes—"The following is his reply: 'Prominent buds, large, smooth, regular, glossy leaves, large leaf stems, short distances between buds and a compact sturdy look, are the best indications of a good apple among seedlings.' I was greatly pleased with this information because it coincided with what I and my friends already believed. So on one occasion when the Horticultural Board of the State, all experienced horticulturists, visited the Experimental Orchard, I asked them to select each a tree that he thought most promising. One tree all

Fig. 3. Aluminum Embossed Labels. (Embossing machine made by Roovers Bros., Brooklyn, N. Y.)

agreed would surely be grand. As they came into bearing nearly every tree was a sweet variety, and the special tree a very small worthless variety. Not a selected tree was of any worth. I had refrained from cutting out trees that I was sure were worthless, because I had had no experience. It was well that I did. We did not know how to select. * * * Consider a few well-known varieties. Grimes and Rambo are thorny. Rambo is especially unpromising in bud appearance. Benoni, the king of summer varieties, is very unpromising both in tree and bud. Jonathan grows so straggling that nurserymen don't like to grow it."

The Permanent Planting.

One of the most perplexing problems in breeding work with orchard fruits is to provide sufficient space for the growth of seedlings until fruit is produced. There are two general plans of procedure, both of which have their advantages and their disadvantages. The first method is to plant the seedlings close together and as soon as they have fruited, to propagate from the most promising ones and to test these under orchard conditions. This is economical of space but there is some question as to the value of this preliminary selection since some trees do not show their true characters unless the trees are allowed full development. The second method is to plant in orchard form as soon as trees are of sufficient size, allowing each tree plenty of room. This would be the ideal method but on account of the lack of available land and funds it has not been feasible at this Station. For future plantings it is hoped that a modification of the two methods can be adopted. By arranging the rows ten feet apart and planting seedlings about ten or twelve feet apart in the row it should be possible to determine fairly well whether a seedling has any promise. Three hundred and fifty to four hundred and fifty trees could be accommodated per acre by following this plan.

Another problem is to label and to keep track of the plantings. The practice at this Station is to place a good permanent stake at the beginning of each lot of seedlings and attach an embossed aluminum label giving the parentage. To each seedling is then attached by a copper wire an aluminum tag bearing a serial number together with the year the seedlings germinated, e. g., 68—'12, the first being the serial number, the other the year. A plat of the planting is also kept on file at the office.

The Fruiting Age.

At best it is a long time to wait for seedling trees to come into bearing. Various expedients have been tried to shorten this period. A number of seedlings were top-worked on dwarf trees but the results were not encouraging. The top-working entailed a good deal of labor, and where several kinds were placed on the same tree it was almost impossible to keep track of them. Besides this many of the seedlings fruited almost as early on their own roots.

Girdling was another method tried. The first plan used was to remove a ring of bark but some of the wounds did not heal readily and later it was found more satisfactory to check the flow of sap by wrapping the branch with a strand of fine wire. When this was done on trees five or six years old about the last of June very good results were secured. One drawback to girdling is the production of numerous water sprouts just below the point girdled. These water sprouts are very susceptible to the fire blight. Summer pruning helps somewhat in controlling them, but it must be done with care or it will only serve to spread the blight around. Frequently the first blossoms appear on the terminal shoots so it seems desirable not to prune these back severely. Even with these expedients, however, one can hardly expect any very great results in breeding work with pears and apples in less than ten or twelve years.

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